THE FAUNA OF THE LOWER CAMBRIAN OR OLENELLUS ZONE.

BY

CHARLES D. WALCOTT.

U.S.GEOLOGICAL SURVEY.

DISTRIBUTION OF THE CAMBRIAN STRATA AS S

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TA AS SHOWN BY SURFACE OUTCROPS IN NORTH AMERICA

By C.D. WALCOTT

300 600 STATUTE MILES.

Scale.

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THE FAUNA OF THE LOWER CAMBRIAN OR OLENELLUS ZONE.

By Charles D. Walcott.

I. DEFINITION OF TITLE.

A living fauna, as known to the zoologist, is the assemblage of animals embraced within a given geographic province or area, and includes all animal life associated on account of climate or physical boundaries. Some of the species may range from province to province and form a part of several faunas, while others are limited to a particular portion of some faunal area.

In the study of the extinct faunas, buried in the rocks, the same general principles of classification prevail, with the added restriction of vertical or time range as defined by the progressive zoologic changes in the faunas.

There is not a sufficient assemblage of species found in the oldest rocks in which animal life has been detected to constitute a fauna that can be characterized either as distinct from the succeeding fauna or as belonging to that fauna. At present the first recognized fauna occurs in the lowest division of the Cambrian Group. In nearly all the localities where this lowest zone is recognized a peculiar genus of trilobites, Olenellus, is found; and thus the names Olenellus Fauna and Olenellus Zone have come into general use. By the paleozoologist the fauna is called the Olenellus or Lower Cambrian Fauna. To the geologist the series of rocks in which the Olenellus fauna occurs is known as the lower division of the Cambrian group or Olenellus Zone.

II. SCOPE OF PAPER.

It is proposed to present (1) a list embracing titles of the more important books and papers relating to the subject; (2) a historical review of the work done on the rocks and fossils now included in the Olenellus Zone; and (3) the general results of the study of the fauna by the geologist and paleozoologist, or its physical and biological history and character as far as known. The geologist considers it as found in certain rocks at a distinct geologic horizon and studies its geologic relations. The paleozoologist treats of it in its relations to the animal world, past and present.

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Nature, vol. 38, 1888, p. 551.

——— Stratigraphic Position of the Olenellus Fauna in North America and Europe.
Am. Jour. Sci., 3d ser., vol. 37, 1889, pp. 374-392; vol. 38, 1889, pp. 29-42.

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CHRONOLOGICAL ARRANGEMENT OF THE PRECEDING LIST BY AUTHORS.

1818. Eaton, Amos.
1819. Dewey, C.
1820. Dewey, C.; Eaton, Amos.
1822. Eaton, Amos.
1824. Dewey, C.; Eaton, Amos.
1828. Eaton, Amos.
1830. Eaton, Amos.
1832. Eaton, Amos.
1836. Sedgwick, Adam.
1838. Sedgwick, Adam.
1841. Rodgers, H. D.; Emmons, E.
1842. Emmons, E.
1843. Jukes, J. B.
1844. Emmons, E.
1845. Adams, C. B.; Bayfield, H. W.
1846. Emmons, E.
1847. Adams, C. B.; Hall, J.
1848. Adams, C. B.; Haldeman, S. S.
1849. Emmons, E.
1850. Fitch, Asa.

1853. Thompson, Zadoc.
1856. Emmons, E.
1859. Emmons, E.; Hall, J.
1860. Emmons, E.; Hall, J.; Marcou, J.
1861. Barrande, J.; Billings, E.; Hall, J.; Hitchcock, C. H.; Hunt, T. S.; Marcou, J.; Rogers, W. B.
1862. Hall, J.; Hitchcock, C. H.
1863. Logan, W. E.
1865. Billings, E.; Logan, W. E.
1866. Hicks, H.; Salter, J. W.; Whitney, J. D.
1867. Hicks, H.; Salter, J. W.; Hitchcock, C. H.
1868. Hicks, H.; Meek, F. B.; Perry, J. B.; Torell, O.
1869. Nathorst, A. G.
1870. Hitchcock, C. H.; Torell, O.
1871. Ford, S. W.; Hicks, H.; Harkness, R.; Linnarsson, G.; Torell, O.
1872. Billings, E.; Ford, S. W.
1873. Dana, J. D.; Ford, S. W.; Hall, J.; Sedgwick, Adam.
1874. Billings, E.; Meek, F. B.; White, C. A.
1875. Brögger, W. C.; Ford, S. W.; Gilbert, G. K.; Hicks, H.; Hitchcock, C. H.
1876. Ford, S. W.; Linnarsson, G.
1877. Dana, J. D.; Emmons, S. F.; Ford, S. W.; Hall, J.; Hicks, H.; Linnarsson, G.; Whitfield, R. P.; Wing, A.; Lundgren, Bernhard.
1878. Ford, S. W.; Hunt, T. S.
1880. Ford, S. W.; Kjerulf, Theo.; Marcou, J.; Roemer, F.
1881. Barrande, J.; Ford, S. W.; Hicks, H.; Nathorst, A. G.
1883. Hague, Arnold; Hunt, T. S.; Linnarsson, G.; Walcott, C. D.
1884. Ford, S. W.; Hitchcock, C. H.; Hunt, T. S.; Walcott, C. D.; Whitfield, R. P.
1885. Dana, J. D.; Perkins, G. H.; Walcott, C. D.
1886. Brögger, W. C.; Hunt, T. S.; Walcott, C. D.
1887. Dana, J. D.; Holm, G.; Hunt, T. S.; McConnell, R. G.; Matthew, G. F.; Walcott, C. D.
1888. Bigot, A.; Foerste, A. F.; Hitchcock, C. H.; Lapworth, Charles; Marcou, J.; Schmidt, F.; Shaler, N. S.; Walcott, C. D.; Woodward, H.
1889. Lapworth, Charles; Walcott, C. D.; Lundgren, Bernhard; Matthew, G. F.; Foerste, A. F.
1890. Matthew, G. F.

IV. HISTORICAL REVIEW.

NORTH AMERICA.

GEOLOGIC INVESTIGATION.

The first attempt in America to assign strata, now referred to the Lower Cambrian, to a definite position in a series of stratified rocks, was made by Prof. Amos Eaton, in 1818, in his "Index to the Geology of the Northern States." In the second edition (1820) he added to the details, and, four years later, published an elaborate section[1] extending from the Atlantic coast line, west, across Massachusetts and New York, to Lake Erie. In this section the relation of the Lower Cambrian "granular quartz" to the "Primitive" gneiss is shown; also the relation of the "transition argillite" to the supposed unconformable calciferous sand-rock of the first greywacke.

[1] Geol. and Agric. Survey of the district adjoining the Erie Canal, pt. 1, 1824.

The portion of the section crossing the outcrops of Cambrian rocks is of such historic interest that it is here reproduced.

FIG. 44.—Section of strata from the Hoosac Mountains to the Hudson River; after Eaton.

As now known the Granular Quartz = Cambrian. The Granular lime rock = Trenton—Chazy—Calciferous limestone. The Primitive argillites of Williamstown Mountain = Hudson shales. The Transition argillite is nearly all Cambrian, with the exception of a small portion near the Hudson River. The Calciferous sand-rock belongs to the Transition argillite series. The Greywacke of Peterboro Mountain is of Upper Cambrian age, and the Metalliferous lime-rock is of Lower Ordovician age. The representation of the geographic distribution and stratigraphic position of the Calciferous sand-rock, Metalliferous lime rock and Greywacke is theoretical, with the exception of the presence of the Greywacke or Peterboro Mountain.

As now known the primitive argillite of the Williamstown range is the Taconic slate of Emmons and the equivalent of the Hudson Terrane or Upper Ordovician of the New York section. The transition argillite is mostly of Lower Cambrian age, and the so-called calciferous sand-rock and greywacke of the section, represented as resting on the upturned edges of the argillite, are portions of the same series to which the argillite belongs. Near the Hudson River a profound fault has thrust the Lower Cambrian strata over on to the Lower Ordovician rocks. The oversight of the true relations of these rocks and a dependence upon their lithologic characters led Prof. Eaton to commit the error that so long remained alive through the writings of Dr. E. Emmons, Prof. Jules Marcou, and Dr. T. S. Hunt.

Prof. Eaton reviewed his work from time to time until 1832,[1] when his final scheme of classification appeared. It is reprinted in the following tabulation, with the equivalents of his formations as known in the nomenclature of to-day.

Eaton's nomenclature (1832).				1889.
II.—Lower secondary:				
3.	Corniferous limerock			Upper Helderberg.
	Geodiferous limerock			Niagara.
2.	Millstone grit and rubble	Second greywacke		Oneida, Clinton, Medina.
1.	Second greywacke slate			Utica, Hudson.
II.—Transition:				
3.	Metalliferous limerock			Trenton.
	Calciferous sandrock			Calciferous.
	Sparry limerock			Trenton, Chazy.
2.	Millstone grit and gray rubble	First greywacke		Middle Cambrian, Ordovician and Silurian.
	Greywacke slate			Hudson.
1.	Argillite	Roof slate		Considerable Hudson, but includes a great mass of Lower Cambrian in Rensselaer County, N. Y.
		Wacke slate		
		Clay slate		
I.—Primitive:				
3.	Granular limerock			Ordovician limestone, Calciferous-Chazy-Trenton.
2.	Granular quartz			Lower Cambrian.
1.	Granite, mica slate, hornblende, and talcose rock			Algonkian, pre-Cambrian, and Archean.

The stratigraphic position of the "granular quartz," (2) of the Primitive, is correctly represented, and it is now known to contain *Olenellus sp. ?* A large portion of the strata referred to the "Argillite," (1) of the transition, is also known to carry *Olenellus asaphoides* and to belong to the Lower Cambrian terrane. In the text

[1] Geol. Text Book, 2d Ed., pp. 68–78.

the "greywacke slate," (2) of the transition, is described as resting unconformably upon the upturned edges of the "argillite" (1) and it is so represented in the section. This is essentially the same as the section of 1820, and as in the more detailed section of 1824. (Ante, Fig. 44, p. 527.)

Rev. Chester Dewey studied the geology of the vicinity of Williamstown, Mass., and, in 1819,[1] published a short sketch of the mineralogy and geology of this region. He followed this in 1820,[2] by a geologic section from the Taconic range in Williamstown to the city of Troy, on the Hudson. In this section the relations of the quartz formation to the mica slates of the Archean are shown, and in a general way the Lower Cambrian slate is described and referred to the transition argillite. In 1824,[3] he described the formations more in detail. His work was contemporaneous with that of Prof. Eaton, but it does not exhibit so comprehensive a grasp of the subject.

Dr. E. Emmons, a pupil of Prof. Eaton, adopted the order of succession of the strata as proposed by Eaton, and separated the "granular quartz" (2), "granular limerock" (3), and "argillite" (1), to form a distinct series of rocks between the "granite" (1) and the "greywacke" (2) of the Transition. To this series of rocks he gave the name "Taconic," as numbers 3 and 1 are largely developed in the Taconic range of mountains. His central idea was that the rocks were non-fossiliferous and beneath the zone of animal life, and were separated, by their mineralogical characters, from the subjacent and superjacent rocks.[4]

In the summer of 1844,[5] Dr. Asa Fitch, a practicing physician, who was better known as an entomologist, discovered fossils in a black slate in Washington County, N. Y., which was referred by Dr. Emmons to the Taconic slate or "argillite" (1), of Eaton. Dr. Fitch sent the fossils to Dr. Emmons, who described from them two species of trilobites, under the names of *Atops trilineatus* and *Elliptocephala asaphoides*.[6] These are the first two described species of the Olenellus fauna. It was not until 1856[7] that Dr. Emmons published

[1] Sketch of the mineralogy and geology of the vicinity of Williams's College, Williamstown, Mass. (With a map.) Am. Jour. Sci., vol. 1, 1819, pp. 337–346.

[2] Geological section from Taconick range, in Williamstown, to the city of Troy, on the Hudson. Am. Jour. Sci., vol. 2, 1820, pp. 246-248.

[3] A sketch of the geology and mineralogy of the western part of Massachusetts and a small part of the adjoining States. Am. Jour. Sci., vol. 8, 1824, pp. 1–60.

[4] Gazetteer of the State of New York; J. Disturnell, I, Albany, 1842, pp. 11-12. Emmons claims the authorship of this paper. Am. Quart. Jour. Agric. and Sci., vol. 4, 1846, p. 208, 2209.

Nat. Hist. New York; Geology, pt. 2; Survey Second Geol. Dist., 1842, pp. 135–164.

[5] Trans. N. Y. State Agric. Soc., vol. 9; Hist. Top. and Agric. Survey, county of Washington, 1850, p. 865.

[6] Taconic System. 4° pamphlet, pp. 19–21, 1844.

[7] Am. Geology, vol. 1, pt. 2, pp. 49-94.

Prof. Eaton's view, that the "argillite" (1) was uncomformably beneath the "greywacke slate" (2), and thus, as he supposed, formed a natural boundary to the upper part of his Taconic system.

In 1860[1] M. J. Barrande identified the fossils, described by Emmons as belonging to the first or primordial fauna, and gave them a fixed position in the geologic scale on paleontologic evidence. He accepted the theory of Eaton and Emmons, that the "argillite" (1) was uncomformably beneath the "greywacke slate" (2), and credited Dr. Emmons with the discovery of the stratigraphic position of the fossils. M. Barrande was misled by the evidence advanced by Dr. Emmons, which was based on the erroneous interpretation of the geological structure by Eaton, in 1824, and followed by Emmons in 1856.[2] The credit of the discovery should be given to M. Barrande.

The review of the results obtained by geologists and paleontologists, other than those mentioned, may be arranged under two general heads: geologic investigation and paleontologic investigation. Within these the geographic distribution is shown by the method of arrangement.

Newfoundland.—Among the early geologic observers Prof. J. Beete Jukes[3] studied the strata about Conception Bay, Newfoundland, and described the relations of the strata now referred to the Olenellus zone to the unconformably subjacent strata of the Algonkian. He mentions the red shales in which the Olenellus fauna occurs, as well as the green and dark shales of the Paradoxides zone.

A little later Captain Bayfield[4] described a sandstone with subjacent red and white limestone, on the straits of Belle Isle, which he stated contained a species of Cyathophyllum. This is the first notice of the Lower Cambrian rocks containing Archæocyathus, and it is the second recorded discovery of fossils of the Olenellus zone.

Eighteen years later Sir William E. Logan[5] described the strata referred to the Olenellus zone in Labrador and Newfoundland, and referred the rocks to the Potsdam group on the authority of the pale-

[1] On the primordial fauna and the Taconic system, by Joachim Barrande, with additional notes by Jules Marcou. Proc. Boston. Soc. Nat. Hist., vol. 7, 1860, pp. 371-376.

[2] Dr. Emmons was a pupil of Eaton and must have known of the view advanced by him in 1824. I am not aware, however, that he credits it to Eaton in any of his publications. Dr. T. S. Hunt mentions (The Taconic Question Restated; Am. Nat., vol. 21, 1887, p. 120, par. 10), that Emmons came forward as the champion of the views of Eaton, but I have been able to discover only one reference to the work of Eaton, and that is merely a list of "Prof. Eaton's classes" of rocks. (No coal in the New York Rocks; Am. Jour. Agric. and Sci., vol. 6, 1847, p. 128.)

[3] General Report of the Geological Survey of Newfoundland, London, 1843, pp. 79-81.

[4] On the Junction of the Transition and Primary Rocks of Canada and Labrador. Quart. Jour. Geol. Soc. London, vol. 1, 1845, pp. 450-459.

[5] Geol. Survey Canada; Rep. Prog. from its commencement to 1863, chapter xi, pp. 287-297.

ontological determinations of Mr. Billings. In the report of the Geological Survey of Newfoundland for 1864 (appendix) he published a table of the Lower Silurian formations in North America, in which the limestone and sandstone on the straits of Belle Isle, on White Bay, Newfoundland, and the slates of St. Albans and Georgia, Vermont, are referred to the Lower Potsdam and to a horizon above the St. John group. This scheme of classification remained unaltered by American geologists until the investigations, by the writer, in Newfoundland during the summer of 1888, proved that the Lower Potsdam fauna of Billings and Logan was beneath that of the St. John group, and was not a portion of the Potsdam fauna.[1] Sir William E. Logan[2] also described the conglomerate beds at Bic, and Trois Pistoles, on the south shore of the St. Lawrence river, where bowlders of limestone were found containing fossils of the Olenellus fauna. The shales in which the bowlders occur are of Lower Ordovician age and contain other bowlders, in which the Upper Cambrian and Lower Ordovician faunas respectively occur.

In the summer of 1888 the writer made a careful study of the Cambrian section in Newfoundland, and determined the Olenellus zone to be beneath the Paradoxides zone and not above it, as arranged by Logan in his scheme of 1864. A detailed section of the Cambrian strata on Conception Bay was published[3] with lists of the fossils occuring at the different horizons in it.

New Brunswick.—The determination of the Lower Cambrian or Olenellus horizon in New Brunswick is of recent date and there is still a little uncertainty as to the actual presence of the fauna. Mr. Matthew reported in 1886 the discovery of *Olenellus* (?) *kjerulfi* in the lower portion of the Cambrian section in the St. John Basin,[4] stating that its position in Europe is beneath that of the beds carrying Paradoxides. On the report of the discovery of the *Olenellus kjerulfi* by Mr. Matthew, Mr. Ford[5] stated that in view of the analysis of the fauna as it occurs in the Cambrian rocks of Sweden, *Paradoxides kjerulfi* was at the base of the series in Sweden and in New Brunswick, but that the trilobite was not a true Olenellus but a Paradoxides. By this interpretation the Olenellus fauna was left in the Middle Cambrian above the Paradoxides zone. Mr. Matthew subsequently explained that he had based the identification of *Paradozides kjerulfi* on fragments that "may belong to this species."[6]

[1] The Stratigraphical Succession of the Cambrian faunas in North America. Nature, vol 38, p. 551.

[2] Geol. Survey Canada: Report of progress from its commencement to 1863, p. 260.

[3] Am. Jour. Sci., 3d ser, vol. 37, 1889, pp. 374–392; vol. 38, 1889, pp. 29–42.

[4] Matthew, G. F., Note on the occurrence of *Olenellus* (?) *kjerulfi* in America. Am. Jour. Sci., III, vol. 31, 1886, pp. 472, 473.

[5] Ford, S. W., Note on the age of the Swedish Paradoxides beds. Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 473–476.

[6] Matthew, G. F., On the kin of *Paradoxides* (*Olenellus ?*) *kjerulfi*. Am. Jour. Sci., 3d ser., vol. 33, 1887, pp. 390–392.

Mr. Matthew continued his investigation in the rocks beneath the Paradoxides zone in the St. John series and discovered a series of sandy shales and red sandstones and gray flags some 1,200 feet in thickness that form a series beneath the true Paradoxides bearing slates.[1] The lower beds of the series carry trails and casts of marine worms and of branching organisms of doubtful relations. This paper was followed a little later by an article on the "Classification of the Cambrian rocks of Acadia," in which the classification of the Cambrian system in Acadia and Newfoundland is as follows:

"Series A.—The Basal Series or Eteminian.

"Series B.—The St. John Group or Acadian.

"Series C.—The Lower Potsdam or Georgian.

"Series D.—The Potsdam Sandstone and Limestone."

Mr. Matthew presents the argument in favor of the view that the Georgian fauna is older than that of the Acadian; and also the evidence in favor of the opposite view that the Acadian is beneath the Georgian, and concludes that the fauna indicates the greater age of the Acadian series.[2] On learning of the discovery of the position of the Olenellus fauna beneath the Paradoxides zone in Newfoundland the terranes were tabulated as follows:

D.—Upper Cambrian, Potsdam series, localities unknown.

C.—Middle and Lower Cambrian, Acadian series, St. John, etc.

B.—Lower Cambrian, Georgian series, C. Breton.

A.—Basal Cambrian, Etcheminian series, St. John, etc.

Of the Olenellus fauna he says: "Though this fauna is found north, east, and west of New Brunswick, having been recognized in Quebec, Cape Breton, and Massachusetts, it has not been found in the Province of New Brunswick, notwithstanding that there are there no less than 1,600 feet of Cambrian measures beneath the Paradoxides beds." He then proceeds to point out the position in these underlying beds where he thinks the fauna will be discovered.[3] Six months later Mr. Matthew published an article "On the Cambrian organisms in Acadia," in which it is stated that he has obtained more definite traces of the Olenellus fauna in the beds subjacent to the Paradoxides fauna.[4] In September of the same year an article appeared under the title of "How is the Cambrian divided?—A plea for the classification of Salter and Hicks." In this Mr. Matthew argues for the uniting of the Olenellus or Lower Cambrian and Para-

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[1] Matthew, G. F., On the Classification of the Cambrian rocks of Acadia. Can. Rec. Sci., vol. 3, 1888, pp. 71–81.

[2] Matthew, G. F.. On a basal series of Cambrian rocks in Acadia. Can. Rec. Sci.; vol. 3, 1888, pp. 21–29.

[3] Matthew, G. F., On the classification of the Cambrian rocks in Acadia. Supplementary note. Can. Rec. Sci., vol. 3, 1889, pp. 303–315, 371, 372.

[4] Matthew, G. F., On the Cambrian organisms in Acadia. Can. Rec. Sci., vol. 3, 1889, pp. 385–387.

doxides or Middle Cambrian, as one division of the Cambrian, and thus divides the Cambrian into two great divisions only.[1]

In the complete paper on "Cambrian Organisms in Acadia"[2] Mr. Matthew describes the section on Hanford Brook and Caton's Island, in which the strata referred to the Lower Cambrian or Basal series occur. These are considered to be unconformably subjacent to the strata carrying the Paradoxides fauna. The associated fauna is fully described and illustrated in the memoir.

Vermont.—In the Vermont or Lake Champlain area, Prof. C. B. Adams,[3] in 1845, described the occurrence of roofing slates in southern Vermont, which he referred to the Taconic slate of Emmons, without further attempt to assign them to a geologic horizon. In 1847,[4] he mentioned his studies of the "Red Sandrock"[5] and noted the discovery of fragments of trilobites, which Professor Hall identified as Conocephalus. He next assigned the "Red Sandrock" to the Upper Silurian, correlating it with the Medina sandstone.[6]

Dr. E. Emmons[7] correlated the "Red Sandrock" with the Potsdam sandstone and Calciferous sandrock, and considered it to be unconformably superjacent to the Taconic slates at Snake Mountain, and at Sharp Shins, near Burlington, Vt.

Prof. William B. Rogers,[8] commenting upon a paper by Prof. C. H. Hitchcock,[9] agreed with him in referring the "Red Sandrock" of Vermont to the horizon of the Medina sandstone of the Silurian, basing his correlation on stratigraphic evidence. Professor Hitchcock, in the same year, described,[10] in the "Geology of Vermont," the "Red Sandrock" series and a quartz rock, leaving in doubt the horizons to which they were to be referred. The Georgia Terrane appears to have been largely correlated with the Hudson River group as then understood.

In 1861[11] Mr. E. Billings noted the correlation of the "Red Sand-

[1] Matthew, G. F., How is the Cambrian divided?—A plea for the classification of Salter and Hicks. Am. Geol., vol. 4, 1889, pp. 139–148.

[2] Trans. Roy. Soc. Canada, vol. 7, sec. 4, 1890, pp. 135–162.

[3] First Ann. Rep. on the Geology of Vermont. Burlington, 1845, pp. 35, 36, 41–43, 50, 61.

[4] Third Ann. Rep. Geol. Vermont, 1847, pp. 14, 31. (See Geol. Survey Vermont, vol. 1, 1861, pp. 339, 340.)

[5] This terrane contains the Olenellus fauna, and is at the base of the Lower Cambrian in Vermont.

[6] On the Taconic Rocks: Am. Jour. Sci., 2d ser., vol. 5. 1848, pp. 108–110.

[7] Am. Geology, vol. 1, pt. 2, 1856, pp. 88, 89.

[8] Notes on the Geological Structure of western Vermont: Boston Soc. Nat. Hist., Proc., vol. 7, 1860, pp. 237–239.

[9] Age of the Rocks of part of Emmons's Taconic System: Boston Soc. Nat. Hist., Proc., vol. 7, 1860, pp. 236–237.

[10] Geology of Vermont, Report, vol. 1, 1861, pp. 326–357.

[11] On some Rocks and Fossils occurring near Phillipsburg, Canada East: Can. Nat., vol. 6, 1861, pp. 323–328.

rock" with the Medina sandstone, and assigned it, on the evidence of the included fossils, to the Potsdam Terrane, to which horizon it has since been referred by most authors who have had occasion to mention it. Mr. Billings also corrected the statement of Professor Hall that the trilobites of the Georgia slate were from the Hudson Terrane, and referred them to the Primordial or Lower Potsdam. This transferred the Georgia series and the associated "Red Sandrock" to the Cambrian.[1]

Sir William E. Logan studied a section in the vicinity of Swanton, Vermont, in which the Georgia slates, with the Olenellus fauna. occur above the "Red Sandrock"[2] beds, and the latter are white and red dolomites with sandy layers. In another section, near the boundary line between the United States and Canada, he found the "Red Sandrock" series largely developed.[3]

In 1867 Prof. C. H. Hitchcock[4] identified the Winooski marble of Vermont with the "Red Sandrock," and stated that *Olenellus thompsoni* occurred in the superjacent slaty layers. In an historical review of the rocks of Vermont[5] he referred the Black Slate, Georgia Slate, Red Sandrock, and Quartzite to the Potsdam group. In this paper he states that these rocks were referred by Rev. Zadoc Thompson in 1842 to the Old Red sandstone and Greywacke, and by Prof. C. B Adams, in 1846, to the Medina sandstone and Hudson River group, in part. In 1875[6] he correlated the Granular quartz of Vermont with the Potsdam sandstone of New York; and, in 1884[7] published a number of geological sections crossing New Hampshire and Vermont, in which the strata of the Olenellus zone are referred to the Potsdam.

The priority for the use of the name Georgia is claimed by Prof. C. H. Hitchcock[8] on the grounds of a better definition of the series of strata now included under the term and the prior use of it as a distinct geologic name. Taking the published literature as authority, it appears that during 1861 volume 1 of the Report on the Geology

[1] New species of Lower Silurian Fossils; on some new or little-known species of Lower Silurian Fossils from the Potsdam Group (Primordial). Geol. Survey Canada, Bulletin, 1861.

[2] Geol. Survey Canada: Report of progress from its commencement to 1863, chapter 11, pp. 280–282.

[3] Op. cit., p. 282.

[4] The Winooski Marble of Colchester, Vermont: Am. Assoc. Proc., vol 16, 1867, p. 119.

[5] The Geology of Northern New England: Vermont, 1870, pp. 1–5, and map. Note added in 1882.

[6] Remarks on the Stratigraphic Structure of the Cambrian and Cambro-Silurian rocks of western Vermont: Boston Soc. Nat. Hist. Proc., vol. 18, pp. 191–193.

[7] Geological Sections across New Hampshire and Vermont: Am. Mus. Nat. Hist., Bull., vol. 1, pp. 155–179, with map and two plates of sections. Reprinted as a pamphlet. Concord, N. H., 1884.

[8] Date of the publication of the Report upon the Geology of Vermont. Proc. Boston Soc. Nat. Hist., vol. 24, 1888, pp. 34–36.

of Vermont was printed, and on the authority of Prof. Hitchcock,[1] excerpts were distributed prior to December, 1861. It is evident that the matter was in print as early as July, 1861, as stated by Prof. Hitchcock.

Prof. Jules Marcou studied the Georgia slate and the "Red Sandrock" series of northern Vermont, and referred[2] the former to the Taconic of Emmons and the "Red Sandrock" to the Potsdam sandstone. Following the lead of Emmons, he drew an imaginary unconformity between the "Red Sandrock" and the superjacent argillites, supposing the latter to be subjacent to the "Red Sandrock." In 1888[3] he corrected, in part, the reference of the "Red Sandrock" to the Potsdam, but represented many of the arenaceous Lower Cambrian rocks as resting unconformably[4] upon the slate series, in which they are interbedded. To explain the evidence of the stratigraphy and fossils he introduced Barrande's theory of "Colonies," and thus theoretically established a remarkable and unique succession of formations in western Vermont. Prof. Marcou referred to the "Black Slates of Georgia," in 1860,[5] and in 1861,[6] used the name "Georgia Slates," in a tabular section of the rocks in Franklin County, Vermont, citing St. Albans, Georgia, Swanton and Highgate Springs as the localities visited by him.[7] In 1888 he claimed priority for the use of the name Georgia in geologic nomenclature.[7]

The writer studied and measured a section that traverses the typical locality of the Olenellus fauna, at Parker's quarry, Georgia, Vt., and discovered *Olenellus thompsoni* in the upper portion of the "Red Sandrock," and determined that the Georgia slates were conformably superjacent to the "Red Sandrock" and contained the same fauna.[8] After reviewing the literature relating to the subject the term Georgia was adopted for the lower division of the Cambrian group of rocks, and credit given to the Geological Survey of Vermont for making the first definite proposal for the use of the name and for giving the first clear definition of it as a term in geology.

[1] Date of the publication of the Report upon the Geology of Vermont. Proc. Boston Soc., Nat. Hist., vol. 24, 1888, p. 34.

[2] Sur les Colonies dans les roches Taconiques des bords du lac Champlain. Bull. Soc. Géol. France, 3d ser., vol. 9, 1880, pp. 18–46, with map and one plate of sections.

[3] The Taconic of Georgia and the Report on the Geology of Vermont. Memoirs Boston Soc. Nat. Hist.. vol. 4, 1888, pp. 105–131, Pl. 13.

[4] Op. cit., Pl. 13, fig. 2.

[5] On the Primordial Fauna and the Taconic System, by Joachim Barrande, with additional notes by Jules Marcou. Proc. Boston Soc. Nat. Hist., vol. 7, 1860, p. 375.

[6] The Taconic and Lower Silurian Rocks of Vermont and Canada. Proc. Boston Soc. Nat. Hist., vol. 8, 1861, pp. 241, 244, 245.

[7] On some Dates of the "Report on the Geology of Vermont." Proc. Boston Soc. Nat. Hist., vol. 24, 1888, p. 87.

[8] Bull. U. S. Geol. Survey, No. 30, 1886, pp. 15–20, Fig. 1.

Prof. J. D. Dana, in 1877,[1] in giving an account of the discoveries in Vermont geology by the Rev. Augustus Wing, speaks of the "Red Sandrock" of Snake Mountain and states that the Rev. Mr. Wing correlated the "Red Sandrock" and the quartzite (granular) and referred them to the Potsdam sandstone. Prof. George H. Perkins published sections of the Winooski marble (Red Sandrock) of Vermont in 1885, and noted the occurrence of *Salterella pulchella* in the marble.[2]

New York and Massachusetts.—The area in western Massachusetts and eastern New York was studied, after Eaton and Emmons, by Prof. H. D. Rogers, who referred the quartzite, at the western base of the Hoosic Mountain, to the white sandstone (Potsdam), and the superjacent Berkshire marble (Granular limerock of Eaton) to the blue limestone (Trenton-Chazy) of the Hudson River Valley.[3] Dr. Emmons next gave an account of these rocks (ante, p. 529), and, in 1850, Dr. Fitch published[4] a geological section crossing Washington County, N. Y. He gave a very clear description of the rocks on the line of the section, including the slates that are now referred to the Lower Cambrian zone.

In connection with the study of the fossils now referred to the Lower Cambrian found in the strata of eastern New York and western Vermont, various views upon their position in the geologic series were expressed by Prof. James Hall. Those first described from near Troy, N. Y., he referred to the Hudson River Group.[5] Subsequently, when studying the trilobites found at Parker's quarry, Georgia, Vt., he referred the fossils to the Hudson River Group, supporting the reference by the statement that Sir Wm. E. Logan assigned the shales containing the fossils to the upper part of the Hudson River Group.[6] In 1861 he changed the reference of these trilobites from the Hudson River Group to the Quebec Group.[7] In a letter written to M. J. Barrande, dated Albany, April, 1862, he explains why he made the preceding references, stating that it was his own conviction that the red sandrock and granular quartz of Vermont were of the age of the Potsdam sandstone and that the schists and shales which held the trilobites he described belonged between the

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[1] An account of the discoveries in Vermont Geology of the Rev. Augustus Wing. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 332–347, 405–419.

[2] The Winooski or Wakefield Marble of Vermont. Am. Nat., vol. 19, 1885, pp. 128–136.

[3] Some observations on the geological structure of Berkshire, Mass., and vicinity, in New York. Proc. Am. Phil. Soc., vol. 2, 1841, pp. 3, 4.

[4] Trans. N. Y. State Agric. Soc.; Hist. Top. and Agric. Survey county of Washington, 1850, pp. 821–822.

[5] Pal. New York, vol. 1, 1847, pp. 256–258.

[6] Trilobites of the shales of the Hudson River Group. 12th Ann. Rep. N. Y. State Cab. Nat. Hist., 1859, pp. 59–62.

[7] Note upon the trilobites of the shales of the Hudson River Group in the town of Georgia, Vt. 13th Ann. Rep. N. Y. State Cab. Nat. Hist., 1860, pp. 113–119.

Potsdam sandstone and the Trenton limestone. He thus changed his views in relation to the age of the rocks containing Olenellus and other trilobites, and referred them to the lower portion of what is now designated as the Lower Silurian or Ordovician. He says:

> You will understand, then, that if my views touching the relations of these rocks are exact, the valley of the Hudson River, from the highlands on the south[1] to Lake Champlain, save a small number of inconsiderable exceptions, is occupied by rocks of the Primordial Zone, that is, by rocks placed between the Potsdam sandstone and the Trenton Group. Thus the Hudson River Group in its typical localities belongs to the Primordial Period."[2]

Following this is the statement that the graptolites found in the beds formerly referred to the Hudson River Group are considered to form a portion of the Primordial fauna.

In 1871, Mr. S. W. Ford[3] published an account of a section of rocks at Troy, N. Y., in which he had found the Olenellus fauna. In 1884,[4] he further added a description of a section to the south of Troy, in Columbia County, N. Y. By the contained fauna he correlated these sections with those described by Sir William E. Logan, in Vermont, Canada, and Newfoundland.

Prof. J. D. Dana, from 1873[5] to 1877,[6] worked out, with considerable detail, the stratigraphic relation of the granular quartz of Berkshire County, Mass., to the subjacent Archean and the superjacent Silurian limestone, adding many details to the general outlines, published by Eaton, Dewey and Emmons.

Dr. T. S. Hunt, 1878,[7] gives an historical review of the rocks referred to the Cambrian and Taconic Systems, and correlates the Upper Taconic with the Cambrian, and refers the Granular Quartz to an Archean System. Again, in 1883–'84–'86,[8] he went over the same ground, but did not add any original information upon the subject. He adopted the view of Eaton that is so well expressed in the section of 1824 (Fig. 44, p. 525), and brought down to 1886 the error of the unconformity between the calciferous sandrock and the argillite.

[1] The word is "north" in the original, but it is evidently an error. The French is "à partie des montagnes du nord."

[2] Letter of Prof. James Hall to M. Barrande. Bull. Soc. Géol. France. 2d ser., vol. 19, 1862, p. 732.

[3] Notes on the Primordial Rocks in the vicinity of Troy, N. Y. Am. Jour. Sci., 3d ser., vol. 2, 1871, pp. 32–34.

[4] Note on the discovery of Primordial fossils in the town of Stuyvesant, Columbia County, N. Y. Am. Jour. Sci., 3d ser., vol. 28, 1884, pp. 35–37.

[5] On the Quartzite, Limestone, and Associated Rocks of the vicinity of Great Barrington, Berkshire County, Mass. Am. Jour. Sci., 3d ser., vol. 6, 1873, pp. 49, 50.

[6] On the relations of the Geology of Vermont to that of Berkshire. Am. Jour. Sci., 3d ser., vol. 14, 1877, pp. 204–207.

[7] Second Geol. Survey. Penn.; E. Special Report on the trap dikes and Azoic rocks of southeastern Pennsylvania. 1878. Pt. I, pp. 32, 33, 44–46, 51–62.

[8] Mineral Physiology and Physiography; A second series of chemical and geological essays. The Taconic Question in Geology. Boston, 1886, pp. 517–686.

To the strata which Dr. Emmons included in the Taconic System in 1842, he gave the name Taconian, and referred them to a pre-Cambrian, Archean, group of rocks. With fossils known from the Granular quartz, Granular limestone, and Transition argillite this theory is now removed to historic literature.

The writer determined the Lower Cambrian age of the purple roofing slates of Washington County, N. Y., in 1886,[1] and in 1887 discovered the Olenellus fauna in situ in the Granular quartz of Vermont.[2] He mapped the strata of Washington and Rensselaer Counties, N. Y., in 1887, and collected fossils from the Lower Cambrian rocks at over one hundred localities. The map and an accompanying section, with a discussion of the work done by Dr. Emmons, was published as a contribution to the question of the use of the name Taconic in geologic nomenclature.[3] In this paper Eaton's and Emmons's theory of an unconformity between the Calciferous Sandrock of the Lower Silurian (Ordovician) and the Lower Cambrian argillites is shown to have been based on an erroneous interpretation of the stratigraphy. The position of the Lower Cambrian rocks is described in the text and exhibited in the section.

Appalachian area south of New York.—The Lower Cambrian horizon has been recognized in one place only in the Appalachian range south of New York. This is at Chilhowee Mountain, Tennessee. The Chilhowee sandstone and shale were placed under the Cambrian system by Safford in 1856.[4] The group is described as consisting of dark gray, micaceous, sandy shales and sandstones, and grayish white quartzose layers, altogether several thousand feet in thickness. The name is derived from Chilhowee Mountain, in Sevier and Blount counties. Near the upper part of the formation many beds of grayish white quartzose sandstones occur which are generally freely pierced by the peculiar rod-like fossils "(*Scolithus linearis*) of the New York Potsdam sandstone."

In the final report on the geology of Tennessee,[5] the Chilhowee sandstone is included under the Potsdam group along with the Ocoee conglomerate and slate below, and the Knox group of slates, shales, dolomites, and limestones above. In the table, on page 169, the Potsdam group is included under the Lower Silurian.

On a visit to Chilhowee Mountain, in 1889, I found that the Chilhowee sandstone was of Lower Cambrian age, from the presence of

[1] Cambrian Age of the Roofing Slates of Granville, Washington County, N. Y Proc. Am. Assoc. Adv. Sci., vol. 35, 1886, pp. 220, 221.

[2] The Taconic System. Am. Jour. Sci., 3d ser., vol. 33, 1887, pp. 153, 154.

[3] The Taconic System of Emmons, and the use of the name Taconic in geologic nomenclature. Am. Jour. Sci., 3d ser., vol. 35, 1888, pp. 229-242, 307-327, 394-401, with map and 13 figures.

[4] Safford, J. M. A geological reconnoissance of Tennessee; 1st biennial report. Nashville, 1856, p. 152.

[5] Safford, J. M. Geology of Tennessee. Nashville, 1869, p. 182.

Lower Cambrian fossils in the banded shales at and near the summit of the formation. From the correlations made by the Rogers brothers in Pennsylvania and Virginia it is more than probable that the quartzites of South Mountain, Pennsylvania, and those resting upon the crystalline rocks in Virginia, beneath the limestones of the Calciferous, Trenton terrane, are of the same age as those of Chilhowee Mountain. This would also include the quartzites, at a similar horizon, in Georgia. The discussion of the literature pertaining to them, however, will be given in a future report, under the general description of the Cambrian rocks of the States mentioned, as there is not yet any positive paleontologic or stratigraphic evidence that the quartzites and sandstones mentioned are of Lower Cambrian age.

Massachusetts.—The discovery by Prof. N. S. Shaler[1] of a small area of Lower Cambrian strata, near North Attleborough, Bristol County, Mass., introduced the Olenellus fauna into the Atlantic Basin, south of Newfoundland. The lithologic characters of the rocks are strikingly like those of the Manuel's Brook section of Newfoundland, and several species of fossils are identical in the two localities.

In 1889 Mr. A. F. Foerste announced the discovery of Hyolithes in the limestone near East Point, Nahant. He correlates the limestone and associated shales with those of North Attleborough, and states that the species of Hyolithes appears to be the same as that found at North Attleborough. He proposes for it the name of *Hyolithes inæquadrilateralis.*[2]

Rocky Mountain province.—The earliest reference to strata containing the Olenellus fauna in the Rocky Mountain Province is by Prof. J. D. Whitney,[3] who mentioned in 1866 the discovery by Mr. J. E. Clayton of Upper Silurian or Devonian fossils at Silver Peak, Nev. The occurrence of the coral-like forms described by Mr. F. B. Meek as *Ethmophyllum whitneyi* doubtless led to this reference. The geologists of the Wheeler Survey traversed Central Nevada, and in 1875 Mr. G. K. Gilbert[4] mentioned the occurrence of Olenellus at Pioche, Nev., assigning it to the Lower Silurian. He also published the descriptions of *Olenellus gilberti* and *O. howelli*, Meek. Mr. S. F. Emmons,[5] of the Geological Exploration of the 40th Parallel, described strata of Cambrian age in the Big Cottonwood Cañon and Ophir Cañon, Utah, stating that *Lingulella ella* and *Olenellus*

[1] On the geology of the Cambrian district of Bristol County, Mass. Bull. Mus. Comp. Zool. Harvard College, 1888, vol. 16, pp. 13–26.

[2] Boston Soc. Nat. Hist., Proc., vol. 24, 1889, pp. 261–263.

[3] Remarks on the Geology of the State of Nevada. Proc. California Acad. Sci., vol. 3, 1866, pp. 266–270.

[4] Geog. and Geol. Expl. and Sur. west of 100th Mer., vol. 3, 1875, pp. 181–183.

[5] Geol. Explo. Fortieth Par., vol. 2, 1877, 405–414, 445.

gilberti occur in the Ophir section, and in 1883[1] Mr. Arnold Hague published an abstract of his report on the geology of the Eureka district, in which he described the stratigraphic position and character of the rocks containing *Olenellus gilberti* in the Eureka district. In 1880 the writer took up the study of the Cambrian rocks in the Rocky Mountains, and in 1886[2] gave a detailed account of the Wasatch section in Utah, and the Eureka district and Highland Range sections of Nevada.

Geologists are indebted to the Geological Survey of Canada for the discovery of the Olenellus zone in the Rocky Mountains of British Columbia. Dr. Geo. M. Dawson first discovered a species of Olenellus like *O. gilberti* at Kicking Horse Lake in British Columbia,[3] and in 1887 Mr. R. G. McConnell described a section at Castle Mountain and Mount Stephen, which shows that the Olenellus fauna occurs at the base of the Castle Mountain limestone, and that the Middle Cambrian fauna occurs 2,000 feet above.[4]

PALEONTOLOGIC INVESTIGATION.

The study of the fauna began with the description of *Fucoides rigida*, *F. flexuosa* (= *Planolites marina*), *Gordia marina* (= *Planolites marina*), *Elliptocephala asaphoides* (= *Olenellus asaphoides*), and *Atops trilineatus* (= *Conocoryphe trilineatus*), by Dr. Emmons.[5] He added another species in 1856,[6] by figuring it under the name of *Diplograpsus secalinus*. This species is described in this paper as *Phyllograptus ? cambrensis*. He described many others of Silurian age, referring them to the Taconic System.

The second description of fossils, now referred to the Olenellus fauna, was made by Prof. James Hall in the Paleontology of New York, vol. i, 1847. Under the title "Description of Fossils of the Hudson River group" the following species were described as new: *Orbicula cælata* (p. 290), *Orbicula ? crassa* (p. 290), *Avicula ? desquamata* (p. 292), *Theca ? triangularis* (p. 313), *Metoptoma ? rugosa* (p. 306), *Palæophycus virgatus* (p. 263), and *Agnostus lobatus* (p. 258). A description and figures are given of *Olenus asaphoides*, Emmons,

[1] Abstract of Report on the Geology of the Eureka District, Nevada. 3d Ann. Rep. Director U. S. Geol. Sur., 1881–1882, 1883, pp. 241–272, with map and plate of sections.

[2] Second Contribution to the studies on the Cambrian faunas of North America. Bull. U. S. Geol. Surv. No. 30, 1886, pp. 30–40, figs. 3 and 4.

[3] Geol. and Nat. Hist. Surv. Can., n. ser. vol. 1, 1886, p. 139.

[4] Report on the geological structure of a portion of the Rocky Mountains. Geol. and Nat. Hist. Surv. Canada, new ser., vol. 2, for 1886, 1887, pp. 28–30 D, with section.

[5] The Taconic System, Pamphlet 4°, Albany, 1844, pp. 20, 21, 24, 26, 1–67, pls. ii, v.

[6] Am. Geol., vol. 1, pt. 2, 1856, p. 104, pl. i. fig. 11.

on pp. 256, 257, pl. 67, figs. 2 a–c. In a later publication[1] he identified Conocephalus and Olenus from the Red Sandrock of Highgate, Vt., but did not assign them to a geologic horizon. In studying a collection sent to him by Rev. Zadock Thompson, Prof. Hall determined and described *Olenus thompsoni*, *O. vermontana*, *Peltura* (*Olenus*) *holopyga*, referring them to the Hudson River group.[2] He supported this reference by the statement that Sir William E. Logan referred the shales containing the fossils to the upper part of the Hudson River group. In 1860[3] he proposed the genus Barrandia to include *Olenus thompsoni* and *O. vermontana*. The genus Bathynotus was formed to include *Olenus* (*Peltura*) *holopyga*. In 1861[4] he changed the reference of these trilobites from the Hudson River group to the Quebec group; and, a little later, made a strong defense of his reference of the fossils of the Georgia slates to the Hudson River and Quebec groups, citing the authority of Sir William E. Logan for the stratigraphic position of the rocks.[5] Discovering that the proposed generic name, Barrandia, was preoccupied he substituted the name Olenellus, in 1862.[6] This is the first introduction of the name which is now given to the Lower Cambrian fauna. The last reference of Professor Hall to the fauna is the proposal of the genus Discinella for what he considered to be a small brachiopod, but which was subsequently shown by S. W. Ford to be the operculum of *Hyolithellus micans*.

The fauna of the "Red Sandrock" of Vermont was first discovered by Prof. C. B. Adams, in 1847[7], who sent the specimens to Prof. James Hall. The latter identified Conocephalus, but did not assign the fossils to any geologic horizon. Professor Adams in 1848[8] mentions the Conocephalus and also an Atrypa, like *Atrypa hemispherica* (= *Camerella ? antiquata*, Billings).

Mr. E. Billings, as paleontologist to the Geological Survey of

[1] Letter from Prof. James Hall on certain fossils in the Red Sandrock of Highgate. Albany, N. Y., Sept. 17, 1847. Third Ann. Rep. Geol. Vermont, 1847, p. 31, Appendix C.

[2] Trilobites of the shales of the Hudson River group. Twelfth Ann. Rep. N. Y. State Cab. Nat. Hist., 1859, pp. 59–62.

[3] Note upon the trilobites of the shales of the Hudson River group in the town of Georgia, Vermont. Thirteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1860, pp. 113–119.

[4] Correction for the Thirteenth Annual Report. Fourteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1861, p. 110. "Page 113, in the title of the article, for 'Hudson River group,' read 'Quebec group.'"

[5] Rep. Geol. Vermont, vol. 1, 1861. Letter from James Hall, paleontologist, of New York, to the editors of the Am. Jour. Sci. and Arts, pp. 382–386.

[6] Supplementary note to the Thirteenth Report, etc. Fifteenth Rep. N. Y. State Cab. Nat. Hist., 1862, p. 114.

[7] Foot-note to Letter on certain fossils in the Red Sandrock of Highgate, by James Hall. Third Ann. Rep. Geol. Survey of Vermont, 1847, p. 31.

[8] On the Taconic Rocks. Am. Jour. Sci., 2d ser., vol. 5, 1848, p. 108.

Canada, took up the study and correlation of the older Paleozoic faunas, and was the first to assign and correlate the fossils described by Professor Hall, to the pre-Potsdam horizon. In 1861[1] he described a number of Lower Silurian fossils from the Potsdam group, and assigned the following species to the horizon of *Paradoxides thompsoni*, of Hall: *Palæophycus congregatus*, *P. incipiens*, *Archaeocyathus atlanticus*, *A. minganensis*, *Obolus labradoricus*, *Obolella chromatica* *O.* (*Kutorgina*) *cingulata*, *Orthisina festinata*, *Camerella antiquata*, *Conocephalites miser*, *C. adamsi*, *C. teucer*, *C. vulcans*, *C. arenosus*. *Bathyurus senectus*, *B. parvulus*, *Salterella rugosa*, *S. pulchella*, and *S. obtusa*. The new genera are Archæocyathus, Obolella, Kutorgina and Salterella.

A little later he published a note on the "Red Sandrock" formation of Vermont,[2] in which he refers the formation to the base of the Lower Silurian somewhere within the horizon of the Potsdam, identifying Conocephalites from it. In reprinting, in 1865 the article published in 1861[3] Mr. Billings added two new species, *Archæocyathus profundus* and *Acrotreta gemma*, and discussed the genus Archæocyathus. On page 371 of the same work he correlates the Primordial fauna of the Red Sandrock of Vermont with that of Newfoundland and Labrador and refers them to the Potsdam group, stating that there is no paleontological evidence of precise similarity of age, but the general affinities and scope of the fossils and the physical relations of the rocks prove that there can be no great difference.

In 1872 Mr. Billings returned to the study of the fossils of the older Paleozoic rocks, and noted the discovery of *Salterella pulchella* in the Winooski marble of Vermont,[4] and also describes some fossils from the Primordial rocks of Newfoundland, the following of which are now referred to the Olenellus zone: *Agraulos strenuus*, *Iphidea* n. gen., *Iphidea bella*, *Stenotheca pauper*, *Scenella*, n. gen., *Scenella*

[1] Geol. Survey Canada, Bulletin, 1861; new species of Lower Silurian fossils: on some new or little known species of Lower Silurian fossils from the Potsdam group (Primordial zone). This paper was republished in the Geology of Vermont, vol. 2, pp. 942–955, 1862 (dated 1861); also, with some changes, in Geol. Survey Canada; Pal. Foss., vol. 1, 1865, pp. 1–18.

[2] On the age of the Red Sandstone formation of Vermont. Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 232.

[3] Geol. Survey Canada, Bulletin, 1861. New species of Lower Silurian fossils. On some new or little known species of Lower Silurian fossils from the Potsdam group (Primordial zone). This paper was republished in the geology of Vermont, vol. 2, pp. 942–955, 1862 (dated 1861); also in the Geol. Survey, Canada, Pal. Foss., vol. 1, 1865, pp. 1–18, with some changes.

[4] Note on the discovery of fossils in the "Winooski marble" at Swanton, Vt Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 145, 146. Can. Nat. 2d ser., vol. 6, 1872, p. 351.

reticulata.[1] In the same year[2] he also described the following genus and species, found in bowlders and pebbles in the conglomerate at St. Simon, below Quebec. The genus Obolella and the species *Obolella gemma, O. circe, Platyceras primævum, Hyolithes americanus, H. communis, H. princeps, H. micans.* On page 240 of the same publication the genus Hyolithellus is proposed for the species *Hyolithes micans.* The work of Mr. Billings was most important, as by it various Cambrian fossils that had been referred to the Hudson and Quebec series of strata were placed in one horizon and correlated with a similar fauna from Labrador and Newfoundland. Upon the data given by Mr. Billings at various times the first classification of the Cambrian rocks was made by Sir William E. Logan.

The Olenellus fauna of northern Vermont was further enlarged, in 1884[3], by Prof. R. P. Whitfield, who described *Orthisina orientalis, Olenoides marcoui,* and *Protypus hitchcocki;* all of these were referred by him to the horizon of the Potsdam sandstone.

The oldest Phyllopod crustacean *Protocaris marshi* was described by the writer in 1884[4] from the Georgia slates of Vermont, where it was found in association with *Olenellus thompsoni* and *O. vermontana.* The latter was referred by him to a new genus, Mesonacis, in 1885[5].

Mr. S. W. Ford began, about 1868, a study of the rocks and fossils of the hills east of Troy, N. Y., from which vicinity the first fossils of the Olenellus fauna, found in New York, were obtained. These were described by Professor Hall in 1847, and referred by him to the Hudson River group. Entering into correspondence with Mr. E. Billings, and comparing the fauna that he found at Troy with that from below Quebec, referred by Mr. Billings to the Lower Potsdam, Ford concluded that the strata containing the fauna at Troy should also be referred to the Lower Potsdam.[6] In his first paper he mentions finding 18 species, 8 of which are referred to described species and 10 remained to be described. Mr. Ford published a number of papers from 1871 to 1885,[7] in which he described the rocks and fossils found in them that occur near Troy, and also a little south of Scho-

[1] On some fossils from the Primordial rocks of Newfoundland. Can. Nat., 2d ser., vol. 6, 1872, pp. 465–479.

[2] On some new species of Paleozoic fossils. Can. Nat., 2d ser., vol. 6, 1872, pp. 213–222.

[3] Bull. Am. Mus. Nat. Hist., New York, vol. 1, 1884, pp. 139–154.

[4] Bull. U. S. Geol. Survey No. 10, 1884, pp. 50, 51, pl. x, fig. 1.

[5] Paleozoic notes; new genus of Cambrian trilobites, Mesonacis. Am. Jour. Sci., 3d ser., vol. 29, 1885. pp. 329–331, 2 figs.

[6] Notes on the Primordial rocks in the vicinity of Troy, N. Y. Am. Jour. Sci. 3d ser., vol. 2, 1871, pp. 32–34.

[7] Descriptions of some new species of Primordial fossils. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 419–422, 4 figs.

Remarks on the distribution of the fossils in the Lower Potsdam rocks at Troy, N. Y., with descriptions of a few new species. Am. Jour. Sci., 3d ser., vol. 6, 1873, pp. 134–140.

dack Landing, in Columbia County. The paleontological work of Mr. Ford gave the first satisfactory interpretation of the geology in the vicinity of Troy. The fossils described by him are: *Archæocyathus (A) rarum, A. (A) rensselaericum, Obolella nitida, Scenella retusa, Hyolithes communis*, var. *emmonsi, H. impar, Agnostus nobilis, Leperditia troyensis, Microdiscus meeki, M. speciosus* and *Solenopleura nana*. One of the most interesting of Mr. Ford's studies is that on the embryonic development of *Olenellus asaphoides*. From the data obtained in this study he decided that the Olenellus fauna followed the Paradoxides fauna in time.[1]

The description of the fauna in the Rocky Mountain province began with Mr. F. B. Meek, who described *Ethmophyllum whitneyi* and *E. gracile* from material collected by Mr. J. E. Clayton, at Silver Peak, Nevada. He referred the fossils to the Lower Silurian and considered them to be related to the corals.[2] In 1874[3] he described *Olenellus gilberti* and *O. howelli* from the Primordial rocks of Nevada. These descriptions were first published in a report by Dr. C. A. White, in 1874.[4] Dr. White also described *Kutorgina pa-*

On some new species of fossils from the Primordial or Potsdam group of Rensselaer County, N. Y. Am. Jour. Sci., 3d ser., vol. 5, 1873. pp. 211–215.

Note on the discovery of a new locality of Primordial fossils in Renssalaer County, N. Y. Am. Jour. Sci., 3d ser., vol. 9. 1875, pp. 204–206.

On additional species of fossils from the Primordial of Troy and Lansingburg, Renssalaer County, N. Y. Am. Jour. Sci., 3d ser., vol. 11, 1876, pp. 369–371.

On some embryonic forms of trilobites from the Primordial rocks at Troy, N. Y. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 265–273, 1 plate.

Note on Microdiscus speciosus. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 141, 142.

On certain forms of Brachiopoda occurring in the Swedish Primordial. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 364–366.

Note on the development of Olenellus asaphoides. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 129, 130.

Note on Lingulella cælata. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 127–129.

Descriptions of two new species of Primordial fossils. Am. Jour. Sci., 3d ser., vol, 15, 1878, pp. 124–127, 1 cut.

Note on the Trilobite, Atops trilineatus of Emmons. Am. Jour. Sci., 3d ser., vol. 19, 1880, pp. 152, 153.

On the western limits of the Taconic System. Am. Jour. Sci., 3d ser., vol. 19, 1880, pp. 225, 226.

Remarks on the genus Obolella. Am. Jour. Sci., 3d ser., vol. 21, 1881, pp. 131–134, 5 figs.

On additional embryonic forms of trilobites from the Primordial rocks of Troy, N. Y. Am. Jour. Sci., 3d ser., vol. 22, 1881, pp. 250–259, 13 cuts.

Note on the discovery of Primordial fossils in the town of Stuyvesant, Columbia County, N. Y. Am. Jour. Sci., 3d ser., vol. 28, 1884, pp. 35–37.

[1] On additional embryonic forms of trilobites from the Primordial rocks of Troy, N. Y. Am. Jour. Sci., 3d ser., vol. 22, 1881, p. 257.

[2] Am. Jour. Sci. and Arts, 2d ser., vol. 45, 1868, pp. 62–64.

[3] MSS. published by Dr. C. A. White, 1874. Geol. and Geog. Expl. and Survey West of the 100th Meridian; Prelim. Rep. Invert. Foss. p. 7.

[4] Geog. and Geol. Expl. and Survey West of 100th Meridian; Prelim. Rep. Invert. Foss., p. 7.

nula and *Acrothele subsidua*, referring them to the Primordial fauna. The Olenellus fauna was enlarged in 1877 by Messrs. Hall and Whitfield[1] describing *Lingulella ella* which was found by the geologists of the Fortieth Parallel survey in Ophir Cañon, Utah. The writer discovered several species associated with *Olenellus gilberti*, in the Eureka District, Nevada, and described *Olenellus iddingsi*, *Kutorgina prospectensis*, *Scenella conula*, *Stenotheca elongata*, and *Anomocare parvum*.[2] In reviewing the material collected at Silver Peak, he identified *Archæocyathus atlanticus*, *Archæocyathus* sp. ?, *Strephochetus* sp. ?, *Hyolithellus princeps*, *Kutorgina* (like *K. cingulata*), and *Olenellus gilberti*[3] and described *Ethmophyllum meeki*.[4]

The review of the Olenellus fauna by the writer, in 1886,[5] resulted in the description of the following new species: *Archæocyathus billingsi*, *Leptomitus zitteli*, *Climacograptus ?? emmonsi*, *Orthis highlandensis*, *Orthisina transversa*, *Scenella ? varians*, *Hyolithes billingsi*, *Microdiscus parkeri*, *Olenoides levis*, *Crepicephalus augusta*, *C. liliana*, and *Oryctocephalus primus*. In 1887[6] he published an account of the discovery of a number of new species of fossils in the Upper Taconic slate of Emmons in Washington County, New York. The new species described are: *Lingulella granvillensis*, *Linnarssonia taconica*, *Orthis salemensis*, *Modiolopsis* (??) *prisca*, *Hyolithellus micans* var. *rugosa*, *Aristozoe rotundata*, *Leperditia* (*I*) *dermatoides*, *Microdiscus connexus*, *Olenoides fordi*, *Solenopleura* (?) *tumida*, *Ptychoparia* (?) *fitchi*, and *Ptychoparia* (?) *clavata*.

Mr. G. F. Matthew,[7] in reviewing the Cambrian fauna from Newfoundland, described one species, *Solenopleura bombifrons*, known only from the Olenellus zone. The writer found it in great abundance about Conception Bay in 1888.

Prof. N. S. Shaler described,[8] in association with Mr. A. F. Foerste, a considerable fauna from the Lower Cambrian strata near North Attleborough, Bristol County, Massachusetts. Among the species the following are new to the fauna: *Stenotheca rugosa* var. *abrupta*, *Stenotheca curvirostra*, *Pleurotomaria* (*Raphistoma*) *attleboroughensis*, *Hyolithes quadricostatus*, *Salterella curvatus*, *Paradoxides wal-*

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[1] Geol. Expl. Fortieth Par., vol. 4, 1877, p. 232.

[2] Paleontology of the Eureka District, Monographs of the U. S. Geol. Survey, 1884, vol. 8, pp. 14–28, 59.

[3] Second contribution to the studies on the Cambrian faunas of North America Bull. U. S. Geol. Survey, No. 30, 1886, p, 38.

[4] Proc. U. S. Nat. Mus., vol. xii, 1889, p. 34.

[5] Bull. U. S. Geol. Survey, No. 30, 1886.

[6] Fauna of the "Upper Taconic" of Emmons in Washington County, New York. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 187–199, pl. i.

[7] On the Cambrian faunas of Cape Breton and Newfoundland. Trans. Roy. Soc. Canada, vol. 4, section 4, 1887, pp. 147–157.

[8] Preliminary description of North Attleborough fossils. Bull. Mus. Comp. Zool., Harvard College, vol. 16, 1888, pp. 27–41, pls. 1, 2.

cotti (equivalent to *Olenellus walcotti*), *Ptychoparia mucronatus* (equivalent to *Agraulos strenuus*), and *P. attleboroughensis*. The discovery of the genus Pleurotomaria is very interesting, as it adds greatly to the vertical range of the genus. Mr. Foerste discovered a species of Hyolithes in the limestones at East Point, Nahant, Massachusetts, and proposed the name *Hyolithes inæquadrilateralis*,[1] identifying it with specimens that occur at North Attleborough. After a study of the type specimens and a number of others collected by Mr. Sears at Nahant, I think this form is identical with *H. communis* var. *emmonsi*.

The presence of the Lower Cambrian or Olenellus fauna in New Brunswick is not yet fully proved, but if the stratigraphy described by Mr. Matthew in his memoir on the "Cambrian organisms of Acadia"[2] be correct the fauna from the basal series is in all probability of Lower Cambrian age. The same memoir describes the stratigraphic position of the fauna, comparing it with the Cambrian fauna of Sweden and Russia. The new genera and species are:

Phycoidella n. g., p. 144.
Phycoidella stichidifera n. sp., p. 144.
Palæochorda setacea n. sp., p. 145.
Hydrocytium (?) silicula n. sp., p. 146.
Microphycus n. g., p. 146.
Microphycus catenatus n. sp., p. 146.
Monadites n. g., p. 147.
Monadites globulosus n. sp., p. 147.
Monadites pyriformis n. sp., p. 147.
Monadites urceiformis n. sp., p. 147.
Radiolarites, n. g., p. 148.
Radiolarites ovalis n. sp., p. 148.
Plocoscyphia (?) perantequa n. sp., p. 148.
Astrocladia (?) elongata n. sp., p. 148.
Astrocladia (?) elegans n. sp., p. 149.
Astrocladia (?) virguloides n. sp., p. 149.
Dichoplectella n. g., p. 149.
Dichoplectella irregularis n. sp., p. 149.
Hyalostella minima n. sp., p. 150.
Obolus (?) major n. sp., p. 155.
Lingulella martinensis n. sp., p. 155.
Leperditia ventricosa n. sp., p. 159.
Leperditia steadi n. sp., p. 160.

He also describes and illustrates:

Buthotrephis antiqua Brongn., p. 144.
Platysolenites antiquissimus Eichw., p. 150.
Obolus pulcher Matth., p. 151.
Volborthella tenuis Schmidt, p. 156.
Psammichnites gigas Torrell, p. 157.
Arenicolites lyelli Torrell, var. minor, p. 159.

From the material collected in Newfoundland and collections from New York and Nevada, there was added to the fauna by the writer the genera Coleoloides, Helenia, and Avalonia, and the species *Archæocyathus dwighti*, *Ethmophyllum meeki*, *Planolites annularius*, *Kutorgina labradorica* var. *swantonensis*, *Obolella atlantica*, *Camerella minor*, *Coleoloides typicalis*, *Hyolithes terranovicus*, *H. similis*, *Helenia bella*, *Agnostus desideratus*, *Microdiscus helena*, *Olenellus (M) bröggeri*, *Avalonia manuelensis*, *Zacanthoides eatoni*, *Solenopleura harveyi*, *S. howleyi*.[3]

[1] Bost. Soc. Nat. Hist., Proc., vol. 24, 1889, pp. 261-263.
[2] Trans. Roy. Soc. Canada, vol. 7, sec. 4, 1890, pp. 135-162.
[3] Proc. U. S. Nat. Mus., vol. xii, 1889, pp. 33-46.

EUROPE.

The first discovery of fossils in strata, subsequently referred to the Olenellus Zone, in Europe, was made by Dr. A. G. Nathorst, at Andrarum, Scania, in 1868.[1] The following year he found fragments of a trilobite, which Dr. Torell named *Paradoxides wahlenbergi* in a scheme showing the position of the strata containing it to be beneath the *Paradoxides hicksi* zone.[2] In 1870 Prof. J. G. Linnarsson found a trilobite in the Cambrian beds of Norway, and in 1871[3] named it *Paradoxides kjerulfi*, but he did not connect it with the Olenellus fauna of America. The latter was first identified in Europe by Prof. W. C. Brögger, who, in 1875, pointed out the fact that the *Paradoxides kjerulfi* of Linnarsson was not a true Paradoxides, but a form more nearly related to the American genus Olenellus.[4] This view was subsequently accepted by Linnarsson.[5] In 1886 Prof. Brögger called attention to the relations of the Olenellus and Paradoxides faunas in Norway and Sweden, and argued that the Olenellus fauna of North America must be beneath the Paradoxides zone, the same as in Scandinavia.[6] Following Brögger's paper came the beautiful memoir of Holm,[7] in which it was proved beyond question that the *Parodoxides kjerulfi* of Linnarsson belonged to the genus Olenellus. This was important, as American paleontologists had not admitted the species to the genus Olenellus on the evidence advanced by Brögger.[8]

In the review of the forms referred to the Medusæ Nathorst refers *Astylospongia radiata* Linnarsson and *Agelacrinus lindstromi* Linnarsson to Medusites, and describes *Medusites favosus*, although the same species had previously been described by Dr. Torell as *Protolyellia princeps*.[9] He also suggests that Eophyton is the cast of the trail of a Medusa.[10]

[1] Om lagerföljden inom Cambriska formationen vid Andrarum i Skåne. Öfvers. Kongl. Vetenskaps-Akad. Förhandl., No. 1, 1869, pp. 61–65.

[2] Petrificata Suecana Formationis Cambricæ Acta Univer., Lundensis. Lunds Univer., Års-Skrift., 1870, vol. 6, p. 4.

[3] Om några försteninger från Sveriges och Norges Primordialzon. Kongl. Vetenskaps-Akad. Förhandl., No. 6, 1871, pp. 789–796.

[4] Fossiler fra Öxna og Kletten. Geol. Fören. Förhandl., Bd. 2, 1875, p. 574.

[5] Om faunan i lagren med Paradoxides ölandicus. Geol. Fören. Förhandl., Bd. 3, 1877, p. 362. De undre Paradoxideslagren vid Andrarum. Sver. Geol. Unders., Ser. C., No. 54, 1883, p. 18.

[6] Om alderen af Olenelluszonen i Nordamerika. Geol. Fören. Förhandl., Bd. 8, 1886, pp. 182–213.

[7] Om Olenellus kjerulfi. Geol. Fören Förhandl., vol. 9, 1887, pp. 493–518.

[8] See Stratigraphic position of the Olenellus Fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, 1889, pp. 374–392; vol. 38, 1889, pp. 29–42.

[9] Petrificata Suecana Formationis Cambricæ. Acta. Univ. Lundensis. Lunds Univer., Års-Skrift, 1870, p. 10.

[10] Om Aftryck af Medusor i Sveriges Kambriska lager. Kongl. Sv. Vetenskaps-Akad. Handl., Bd. 19, 1881, No. 1, pp. 34, pl. 6.

In Norway Professor Kjerulf described in his beautiful memoir[1] the lower portion of the Paleozoic section, giving descriptions and figures of many sections.

The discovery of the Olenellus Zone in Russia was described by Dr. F. Schmidt,[2] in 1888. The remains of a trilobite were found by Herr A. Mickwitz, in Estland, on Kunda Brook. The section was studied by Dr. Schmidt, who published it and compared it with the Cambrian section in Norway and Sweden. The list of species found is given in the paper under the head of geographic distribution.

In Britain Prof. Adam Sedgwick described a series of strata, in 1835,[3] that he called Lower, Middle, and Upper Cambrian. In this series the Lower Cambrian included Archean rocks; the Middle Cambrian embraced the roofing slates, etc. (or the Cambrian System, as defined in this paper), and the Upper Cambrian much of the Ordovician (Lower Silurian). The crystalline Archean rocks were excluded from the Cambrian in 1838,[4] and the Lower Cambrian made to include the old slate series, up to the Bala, and the Upper Cambrian, the Bala series. The lower division was subsequently separated into the Bangor group and the Festiniog group, or the Lower and Middle Cambrian. Subsequently the Lower Cambrian was made to include the Longmynd, Bangor, and Llanberis groups.[5] This is the last expression of opinion from the illustrious founder of the Cambrian System as to what strata should be included in the Lower Cambrian.

The strata embraced in the Lower Cambrian by Sedgwick were mapped and worked up, in detail, in North Wales, by the members of the Geological Survey, but it was not until Dr. Hicks began his work in South Wales that it assumed greater importance as a distinct stratigraphic division. Dr. Hicks presented the results of his investigation in a number of papers published, at intervals, from 1866 to 1886. An excellent summary of this work was given in 1881.[6]

The Olenellus fauna was first recognized and described in Britain by Prof. Charles Lapworth.[7] At the Cumley quarries, Little Caradoc, Shropshire, he obtained *Olenellus calevi* (like *O. bröggeri*), Hyolithellus, Kutorgina, Scenella, Ptychoparia, and Obolella from calcareous sandstone, in the Cumley sandstone. The stratigraphic position of the sandstone, in relation to the Paradoxides zone, was not

[1] Die Geologie des südlichen und mittleren Norwegen. Bonn, 1880.

[2] Ueber eine neuentdeckte untercambrische Fauna in Estland. Mém. Acad. Imp, Sci. St. Pétersbourg, ser vii, vol. 36, No. 2, 1888, pp. 1-27, pls. 1, 2.

[3] Rept. Fifth Meeting Brit. Assoc. Adv. Sci., Dublin, 1836, Trans. of sec. pp. 59-61.

[4] Proc. Geol. Soc. London, vol. 2, p. 679.

[5] Cat. Coll. Cam. & Sil. Foss., Geol. Mus. Univer. Cambridge, 1873. Preface, p. xv.

[6] Classification of the Eozoic and Lower Palæozoic rocks of the British Islands. Pop. Sci. Review, new ser. vol. 5, 1881, pp. 289-308, 2 plates, and one plate of sections.

[7] Nature, vol. 39, 1888, pp. 212, 213. Advanced sheets dated Oct. 25, 1888.

known until the fauna proved that it belonged to the Lower Cambrian.

The details of the stratigraphy and lists of the fossils are given under Geographic Distribution, Section VIII, p. 566.

V. THE LOWER CAMBRIAN OR OLENELLUS ZONE, AS KNOWN TO THE GEOLOGIST.

TYPICAL LOCALITY.

The type locality of the Cambrian Group is in the ancient area of Cambria, in North Wales, where the Middle and Upper Cambrian faunas occur; and the strata corresponding in position to those containing the Lower Cambrian fauna in America are found beneath the Middle Cambrian Zone. The group is characterized by the "First or Primordial Fauna" of Barrande. In America geologists include in it a series of strata that are subjacent to the Calciferous sandrock of the Ordovician group and superjacent to strata referred to the Algonkian group, as shown in the following table:

TABLE SHOWING THE CLASSIFICATION OF THE STRATA OF THE PALEOZOIC AND SUBJACENT SYSTEMS.

System and Group.	
Paleozoic:	
Carboniferous	Permian. Coal Measures. Lower Carboniferous.
Devonian	Catskill. Chemung. Hamilton. Corniferous. Oriskany.
Silurian	Lower Helderberg. Niagara.
Ordovician,	Lorraine. Trenton. Chazy. Calciferous.
Cambrian	Potsdam. Acadian. Georgia.
Algonkian:	
Keweenawan	Keweenaw Series. Grand Cañon Series. Llano Series etc.
Huronian Other groups	Lake Superior. Minnesota. Adirondack. Newfoundland etc.
Archean:	
Laurentian	Including Upper Laurentian.

To enable the reader more definitely to locate the Olenellus or Lower Cambrian zone, the classification of the strata embraced by the Cambrian Group in America is presented in the following table.

TABLE SHOWING CLASSIFICATION OF THE CAMBRIAN GROUP.

Cambrian		Lower Calciferous.	Lower portion of the Calciferous sandrock of New York and Canada; Lower Magnesian limestone of Wisconsin, Missouri, etc.
	Upper Cambrian.	Potsdam	Potsdam sandstone of New York, Canada, Wisconsin, Texas, Wyoming; Gallatin limestone of Montana, and a portion of Pogonip limestone of Nevada.
		Knox	Knox Shales of Tennessee; Coosa Shales of Georgia and Alabama. The Alabama section may extend down into the Middle Cambrian.
		Tonto	Tonto Calcareous Shales of Arizona.
		Bell Isle	Shales and sandstones of Great and Little Bell and Kelley's Islands, Conception Bay, Newfoundland.
	Middle Cambrian.	St. John, Braintree, Avalon	Shales and slates of Braintree, Massachusetts: St. John, New Brunswick, and the Avalon Peninsula of Newfoundland. Central portions of the New York and Nevada Cambrian sections, and portions of the Tennessee and Alabama sections.
	Lower Cambrian.	Georgia	Georgia Shales and "Granular Quartz" of Vermont, Canada, New York, and Massachusetts. Shales and quartzite of Chilhowee Mountain, Tennessee.
		Placentia[1]	Limestones, etc., of L'Anse au Loup, Labrador; northwest coast and peninsula of Avalon, Newfoundland; basal series of Hanford Brook, New Brunswick; and shales and limestones of North Attleborough, Mass.
		Prospect	Lower part of Cambrian section of Eureka, and Highland Range, Nevada; Upper Arenaceous Shales of Big Cottonwood Cañon, Cambrian section of Utah.

The divisions of Lower, Middle, and Upper Cambrian are recognized in America and Europe. The names of the subdivisions of these three primary divisions of the group in America are the names of typical terranes that are respectively included in each of the primary divisions. Thus, under the term Prospect, of the Lower Cambrian, are included the strata of the Olenellus zone in Nevada, Utah, and the Rocky Mountain region to the north into British America. The typical section is that crossing Prospect Mountain, in the Eureka district, Nevada. In this section the sedimentation and fauna are essentially the same as in the Rocky Mountain Province. Under the name Placentia are included the strata of the Olenellus zone of northwestern and southeastern Newfoundland, New Brunswick, and eastern Massachusetts; and under Georgia the great development of Lower Cambrian rocks in eastern New York and Vermont and along the St. Lawrence River and south of New York from New Jersey to Alabama.

The names used in the third column refer to strata that are considered to be of the same relative geologic age. Thus the Potsdam, Knox, Tonto, and Bell Island rocks are all of Upper Cambrian age; but no one of them is considered in the table as subjacent or superjacent in stratigraphic position to the other.

[1] This is substituted for the name Terra Nova used in a former table. Am. Jour. Sci., 3d ser., vol. 37, 1889, p. 383.

BASE OF THE OLENELLUS ZONE.

The base of the Olenellus zone is considered to be where the genus Olenellus, or the fauna usually accompanying it, first appears; beneath that horizon the strata are referred to some of the pre-Cambrian groups of rocks. In some cases the underlying rocks are in layers, conformably beneath the Cambrian, and no physical separation of the two groups is possible. In other instances the subjacent rocks are the remains of the old Archean continent, near the shores of which much of the life of this portion of the Cambrian period existed. To exhibit the actual relation of the strata of the Olenellus zone to the subjacent and superjacent rocks, figures of a few typical sections are introduced. The first is that crossing Prospect Peak in the Eureka district, Nevada.

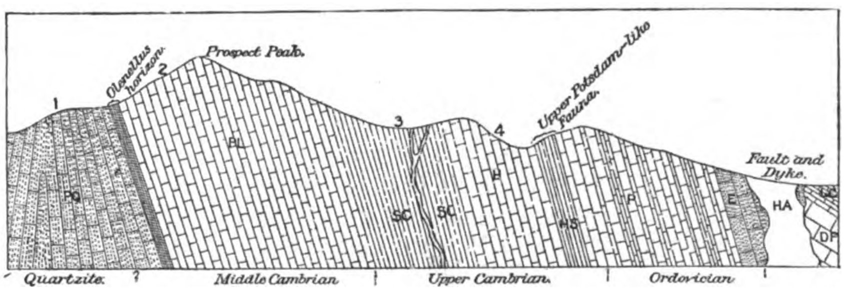


FIG. 45. Eureka section. This section includes the quartzite referred to the Algonkian on the west and conformably superjacent to it the Olenellus zone, above which the limestone of the Cambrian extends upward to the Ordovician.

The numbers on the upper line, and the letters on the section = 1&PQ, Prospect Mountain quartzite; 2&PL, Prospect limestone; 3&SC, Secret Cañon shale; 4&H, Hamburg limestone; HS, Hamburg shale; P, Pogonip limestone; E, Eureka quartzite. At this point the section is broken by massive dikes of hornblende andesite.

Eureka section of Nevada.—In this section (Fig. 45) the Olenellus zone occupies a narrow belt of sandy shale and limestone that rests conformably upon a quartzite that exceeds 1,500 feet in thickness. This same quartzite occurs beneath the Olenellus zone in other sections in Nevada, and has a thickness of more than 10,000 feet in some instances. Above the Olenellus zone the limestones contain a fauna that may be referred to the Middle Cambrian, and still higher the Upper Cambrian fauna is largely developed. The layers of rock are now upturned at an angle of 70°, but as originally deposited they were level, or nearly so.

Wasatch section of Utah.—The second section is that of the Wasatch Mountain uplift in Utah (Fig. 46). The Olenellus zone occupies a thin belt of arenaceous strata just beneath the Middle Cambrian zone much as in the Eureka section (Fig. 45). Beneath it there are over 11,000 feet of strata that are referred to the Algonkian period, as no fossils have been found in them. The Upper Cambrian is absent either by nondeposition, or if deposited, the rocks have been

removed by subsequent erosion. At present the basal line of the Cambrian in Utah and Nevada is drawn at the bottom of the band

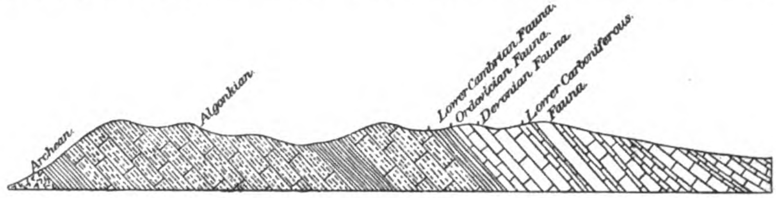


FIG. 46. Wasatch section. This crosses the Wasatch Mountains a little south of Big Cottonwood Cañon. The strata from the Archean to the band of shale carrying the Lower Cambrian fauna is referred to the Algonkian. The strata of the Olenellus zone rest conformably upon the Algonkian rocks, and are conformably subjacent to the strata containing the Middle Cambrian fauna which, in turn, are conformably subjacent to the strata containing the Ordovician fauna.

of arenaceous shales carrying the Olenellus fauna. This refers the quartzites and siliceous shales of the Wasatch and similar sections, including that of the Eureka district and Highland range of Nevada, to the Algonkian system.

Mt. Stephen section of British Columbia.—A somewhat similar section to that in the Eureka district is described by Mr. R. G. McConnell as occurring in British Columbia.[1] It crosses Cathedral Mountain and Mt. Stephen on the eastern side of the Rocky Mountains near the line of the Canadian Pacific Railway. In this section (Fig. 47) the Olenellus fauna occurs in the lower portion of the Castle Mountain limestone (A) and the Middle Cambrian fauna 2,000 feet above, and still higher in the series (B) the Lower Ordovician

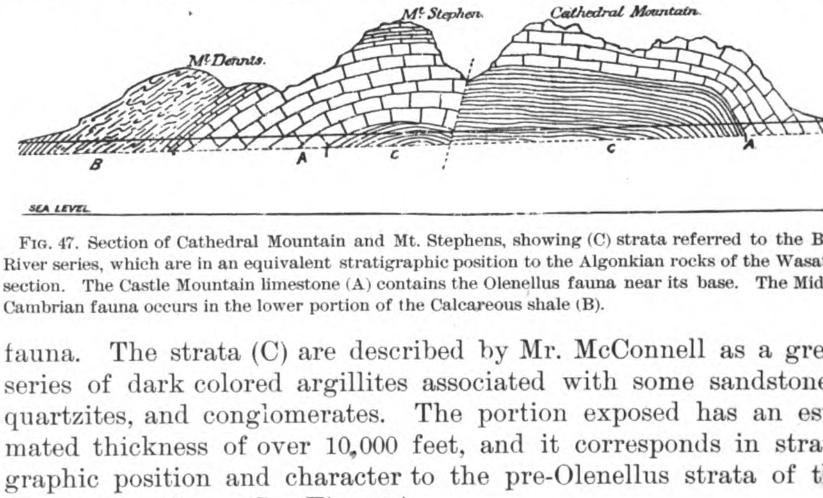


FIG. 47. Section of Cathedral Mountain and Mt. Stephens, showing (C) strata referred to the Bow River series, which are in an equivalent stratigraphic position to the Algonkian rocks of the Wasatch section. The Castle Mountain limestone (A) contains the Olenellus fauna near its base. The Middle Cambrian fauna occurs in the lower portion of the Calcareous shale (B).

fauna. The strata (C) are described by Mr. McConnell as a great series of dark colored argillites associated with some sandstones, quartzites, and conglomerates. The portion exposed has an estimated thickness of over 10,000 feet, and it corresponds in stratigraphic position and character to the pre-Olenellus strata of the Wasatch section. (See Fig. 46.)

Grand Cañon section of Arizona.—The section (Fig. 48) laid bare in the Grand Cañon of the Colorado, beneath the great unconform-

[1] Report on the Geological Structure of a portion of the Rocky Mountains. Geol. and Nat. Hist. Sur. Canada, n. ser., vol. ii for 1886, 1887, pp. 28–30 D, with section.

ity at the base of the known Cambrian, shows 12,000 feet of unaltered sandstone, shales, and limestones, that, I think, were deposited in pre-Cambrian time and should be referred to the Algonkian.

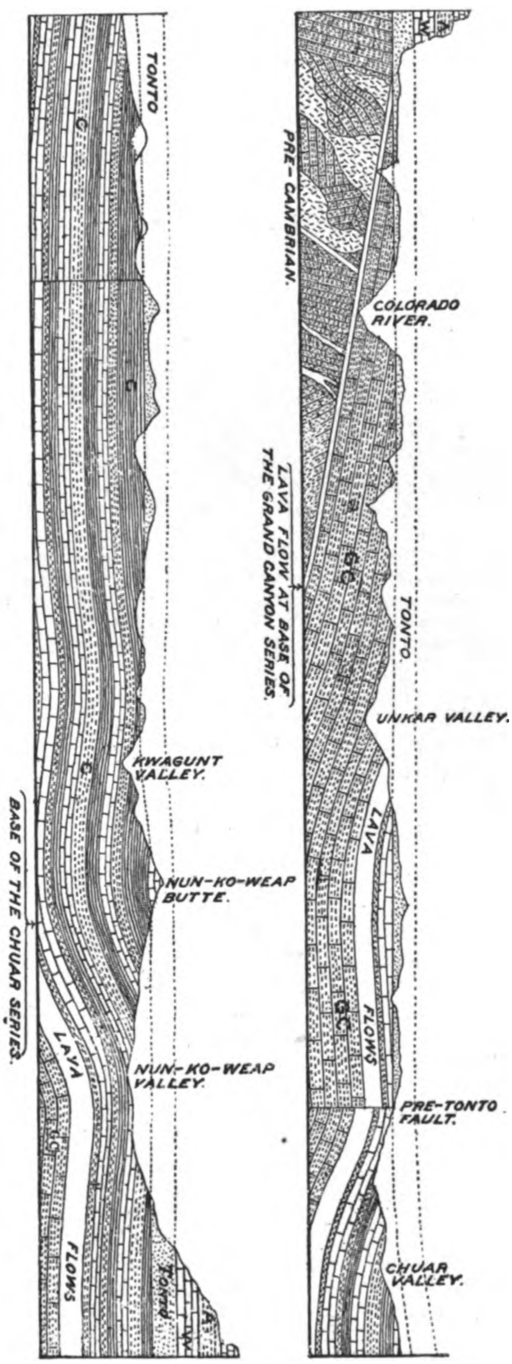


FIG. 48.—Grand Cañon Section. This section crosses the Algonkian strata nearly at right angles to their strike and illustrates the unconformity between the Cambrian and Algonkian rocks. The Cambrian (Tonto formation) has been removed by erosion on the direct line of the section, but it is shown on the sides of the cañon as indicated by the dotted lines. *GC* and *C'*, Grand Cañon and Chuar formation, or the strata referred to the Algonkian. *T*, the Tonto formation of the Cambrian. *W*, Redwall limestone of the Lower Carboniferous. *A*, Aubrey sandstone of the Carboniferous.

The entire section of pre-Cambrian strata is unbroken, and the sandstones, shales, and limestones are much like those of the Ordovician section of New York. In a bed of dark argillaceous shale, 3,550 feet from the summit of the section, I found a small Patelloid or Discinoid shell, a fragment of what appears to be the pleural lobe of a segment of a Trilobite, and an obscure, small Hyolithes, in a layer of bituminous limestone. In layers of limestone, still lower in the section, an obscure Stromatoporoid form occurs in abundance.[1] These fossils indicate a fauna, but do not tell us what it is. A similar series of rocks (Fig. 49) occur unconformably beneath the Cambrian, in Llano County, Tex. Fossils have not been reported from them.[2]

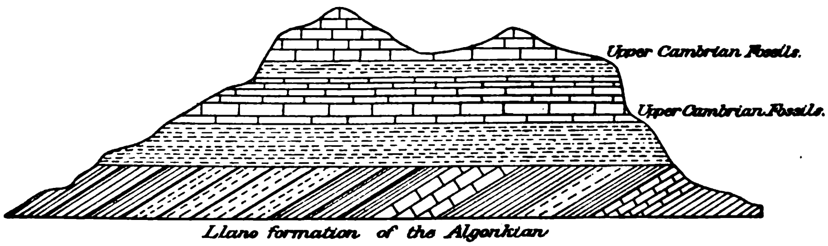


FIG. 49.—Section of Packsaddle Mountain, Texas, illustrating the same unconformable relation of the Cambrian to the Algonkian as shown by Fig 48. The lower horizontal sandstone of the Cambrian is equivalent in position and lithologic characters to the Middle Cambrian lower Tonto sandstone of Arizona, but no fossils have been found to further establish the correlation; the limestone capping the mountain may possibly pass up into the base of the Ordovician, but the typical fauna has not been found in it.

Eastern New York section.—The most puzzling of all the sections is that of eastern New York where the Olenellus fauna ranges through a great thickness of shales and slates—I have estimated it at 14,000 feet—but such a range for a species or subfauna is without precedent, and I wish to review the section before giving a final opinion. The vertical range *is very great* and the base of the Cambrian is unknown.

Vermont section.—In the northern Vermont section the Olenellus zone extends from the upper portion of the limestone through a considerable thickness of shales as shown by the section, Fig. 50. Beneath the Olenellus zone there are about 700 feet of conformably bedded limestones that have not yielded characteristic fossils.[3]

[1] Am. Jour. Sci., 3d ser., vol. 26, pp. 437–442, 1883.

[2] Notes on Paleozoic rocks of Central Texas. Am. Jour. Sci., 3d ser., vol. 28, pp. 431–432, 1884. By an error in the sketch the strata are represented as dipping in the wrong direction. The dip at the point where the section crosses is 15° to 40° south (loc. cit., p. 431). A misprint in the description of the figure refers 5 to the Potsdam *sandstone* instead of *limestone*.

[3] As this is going through the press I wish to record my discovery, in August, 1890, of Salterella and fragments of a trilobite about 500 feet lower down in this section.

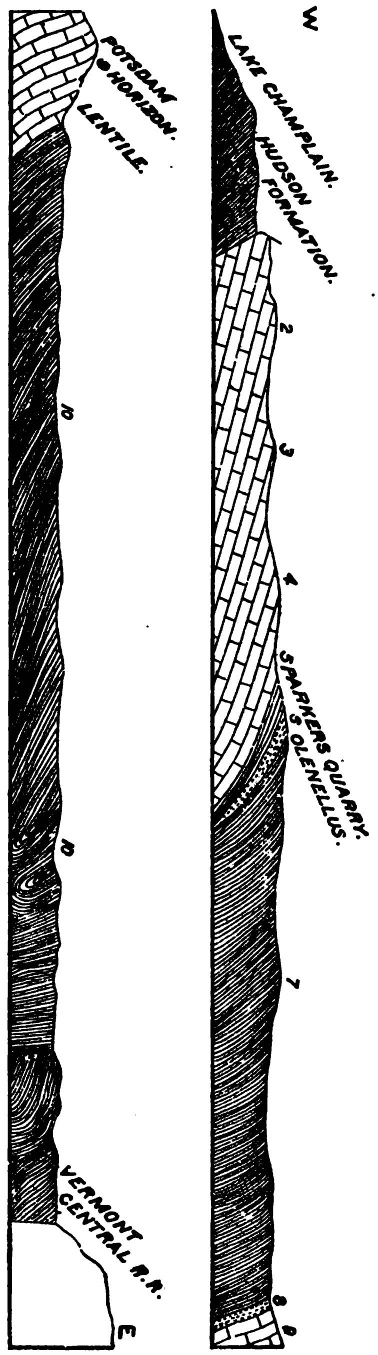


FIG. 50.—Section crossing from Lake Champlain east to the Vermont Central Railroad track, in the town of Georgia, Vt. At 1, an overthrust of the Lower Cambrian on the shales of the Hudson formation is shown. At 5 and 6 the Olenellus fauna is largely developed, and at 9 a few species occur which may belong to the Middle or the Upper Cambrian fauna.

High up in the section an interbedded limestone occurs that contains a fauna that may prove to be a portion of the Middle or it may be the Upper Cambrian fauna. In the St. Lawrence and Hudson valleys there is but one area known where the Lower Cambrian strata rest on the Algonkian and Archean rocks; this is in southern Vermont and western Massachusetts. Here the Olenellus zone is represented by a quartzite that was a sandy sea beach upon which the remains of a species of Olenellus were scattered and buried in the sand by the action of the waves. On the western or Adirondack side of

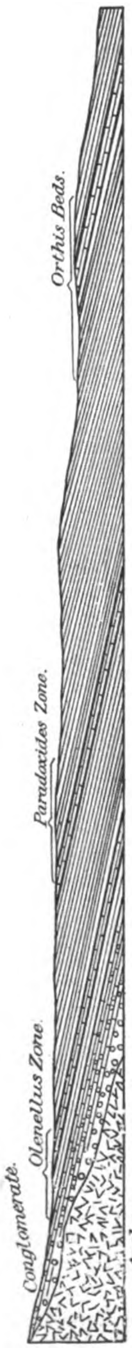


Fig. 51.—Section on Manuel's Brook, Newfoundland. The strata of the Lower Cambrian rest unconformably upon the Archean. Above the conglomerate the shales and sandstone, etc., dip at an angle of 12°, and are conformable through the Olenellus and Paradoxides zones and into the Orthis beds where the section is cut off by the sea.

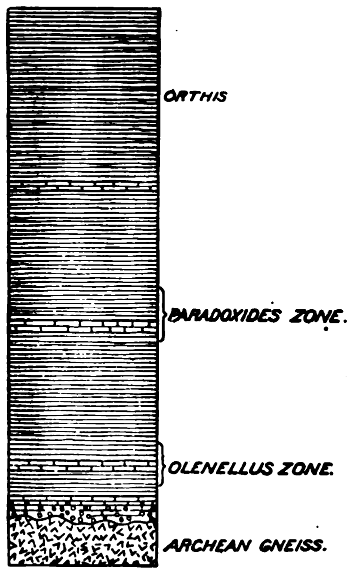


Fig. 52.—Restoration of the section represented by Fig. 51, to show a direct superposition of the Paradoxides zone upon the strata of the Olenellus zone.

the Cambrian Strait the Upper Cambrian sandstone rests unconformably upon the strata of the Algonkian; and the Lower Cambrian appears a few miles to the eastward, where it is brought up to view by a profound displacement of the strata.

Newfoundland section. — In Newfoundland a section is found, on Manuel's Brook, Conception Bay, that exhibits very clearly the stratigraphic relation of the Olenellus and Paradoxides faunas[1] (Figs. 51 and 52). At the base of the section a bed of conglomerate outlines the coast line of early

[1] Stratigraphic position of the Olenellus fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, 1889, p. 380.

Cambrian time. The passage from coarse to fine sediment, in the upper beds of the conglomerate, indicates a gradual depression of the sea bed and the presence of deeper and more quiet waters, where the animal life of the time flourished, died, and became embedded in the soft mud that is now found transformed into clay shale and arenaceous limestone. Of the fossils found in these beds twenty-two species have been identified, all of which belong to the Olenellus fauna. Passing above the red and greenish shale of the Olenellus zone, and searching the layers of greenish shale above, we find, 270 feet above the bed of conglomerate, numerous traces of the Middle Cambrian or Paradoxides fauna; and in the immediately superjacent black argillaceous shales the latter fauna is very abundant in genera, species, and numbers of individual specimens. This is the only section known to me on the American continent where the two faunas are typically developed and occur in an unbroken, continuous, conformable geologic section.

The Manuel's Brook section is typical of the sections of the Atlantic Province of the Lower Cambrian. In Sweden strata containing the Olenellus fauna rest unconformably upon the Algonkian or Archean rocks, and the Paradoxides zone is higher up in the section. In Britain the Lower Cambrian strata rest unconformably upon the Algonkian rocks, and nowhere in the Atlantic Basin area is there any considerable thickness of strata known between the Olenellus zone and the unconformably subjacent pre-Cambrian rocks except it be on St. Mary's and Placentia Bays, Newfoundland.

Cambrian and pre-Cambrian.—The line of demarkation between the Cambrian and pre-Cambrian rocks may be considered as:

First. At the base of the Olenellus zone, in the continuous sections like those of Nevada and Utah.

Second. At the line of unconformable contact between any member of the Cambrian group and the subjacent Algonkian and Archean rocks in the interior area, or over the pre-Potsdam or Keweenawan continent.

Third. At the line of unconformable contact and the base of the Olenellus zone, in the Atlantic Basin, as shown by the sections of Newfoundland and Wales.

The Olenellus zone is so small a factor in the discussion of the geologic features of Europe that the observations thereon, properly belonging under this head, are united with those under "Geographic Distribution," Section VIII.

VI. THE NORTH AMERICAN CONTINENT DURING CAMBRIAN TIME.

The study of the known geographic distribution of the strata of the Olenellus zone and their relations to the subjacent and superjacent rocks has led to conclusions respecting the condition and growth of the continent during Cambrian and late Algonkian time that are worthy of greater consideration than can now be given to them, and I shall only touch upon the points that bear more directly upon the history of the Olenellus zone and fauna.

HABITAT OF THE OLENELLUS FAUNA.

One of the most important conclusions is that the fauna lived on the eastern and western shores of a continent that, in its general configuration, rudely outlines the North American continent of to-day. Strictly speaking the fauna did not live upon the outer shore facing the ocean, but on the shores of interior seas, straits, or lagoons that occupied the intervals between the several ridges that rose from the continental platform east and west of the main continental land surface of the time. On the eastern side, the first ridge east of the main portion of the continent, was the range extending from Alabama to the northeast along the line of the present Appalachian range and its extension to the north, as the Green Mountains, as far as the St. Lawrence. Whether or not the fauna existed in the Connecticut basin of the New England States to the eastward of the Green Mountains is unknown. That it occurs on the eastern side of the next ridge to the east is shown by its presence in eastern Massachusetts and northwestern Newfoundland; its presence in a still more easterly basin is proved by its occurrence on the peninsula of Avalon, to the eastward of the Archean ridges crossing central Newfoundland.

The occurrence of these basins between the Archean ridges of the pre-Cambrian continental platform has been shown by Dana and Crosby, and the presence of similar basins upon the western side have been pointed out by Dana. In one of the latter, between the Wasatch and Sierra-Nevada ranges, the Olenellus fauna flourished, and it also extended to the northward, cutting across a break in the eastern range so as to occupy the eastern shore of the eastern range of mountains in British Columbia.

It is not my intention to discuss the evidence upon which the presence of these various outlying basins is asserted. This has lately been presented by Dana.[1] What I wish to call attention to now is that the Olenellus fauna lived upon the eastern and western sides of

[1]Areas of continental progress in North America, and the influence of the conditions of these areas on the work carried forward within them. Bull. Geol. Soc. America, vol. 1, 1889, pp. 36–48. Archean axes of eastern North America; Am. Jour. Sci., 3d ser., vol. 39, 1890, pp. 378–383.

the mainland of the North American continental area that existed during late Algonkian and early Cambrian time. This view is sustained by the following observations: (1) The strata containing the Olenellus fauna are known only in the eastern and western portions of the continent; (2) as far as known the Lower Cambrian strata are absent in the interior of the continent; (3) the Upper Cambrian strata are unconformably superjacent to the Algonkian and Archean rocks, over the areas where the Middle and Lower Cambrian formations are absent; (4) the strata of the Middle and Lower Cambrian are conformably beneath the Upper Cambrian on the eastern and western sides of the present continent in all sections where the three divisions are present.

In order to present graphically the data for the preceding statements, I have prepared an outline map of the continent, upon which are arranged typical geologic sections of the Cambrian and, when known, the immediately subjacent Algonkian or Archean rocks (Plate XLIV). On this map each section represents the strata of a geographic province or area of greater or less extent. Thus the most western section, B, that of the Eureka district, Nevada, is typical of the Cambrian rocks in the Great Basin area, with the exception of the western slope of the Wasatch Mountains. The section H is considered typical of the Cambrian rocks of the upper Mississippi Valley, etc., etc.

DESCRIPTION OF MAP AND SECTION, PLATE XLIV.

PLATE XLIV. Outline map of the North American Continent, with diagrammatic sections so arranged as to illustrate the comparative thickness of the Cambrian rocks over the interior of the continent and on the eastern and western margins. The star at the base of each section indicates the geographic location of the section.

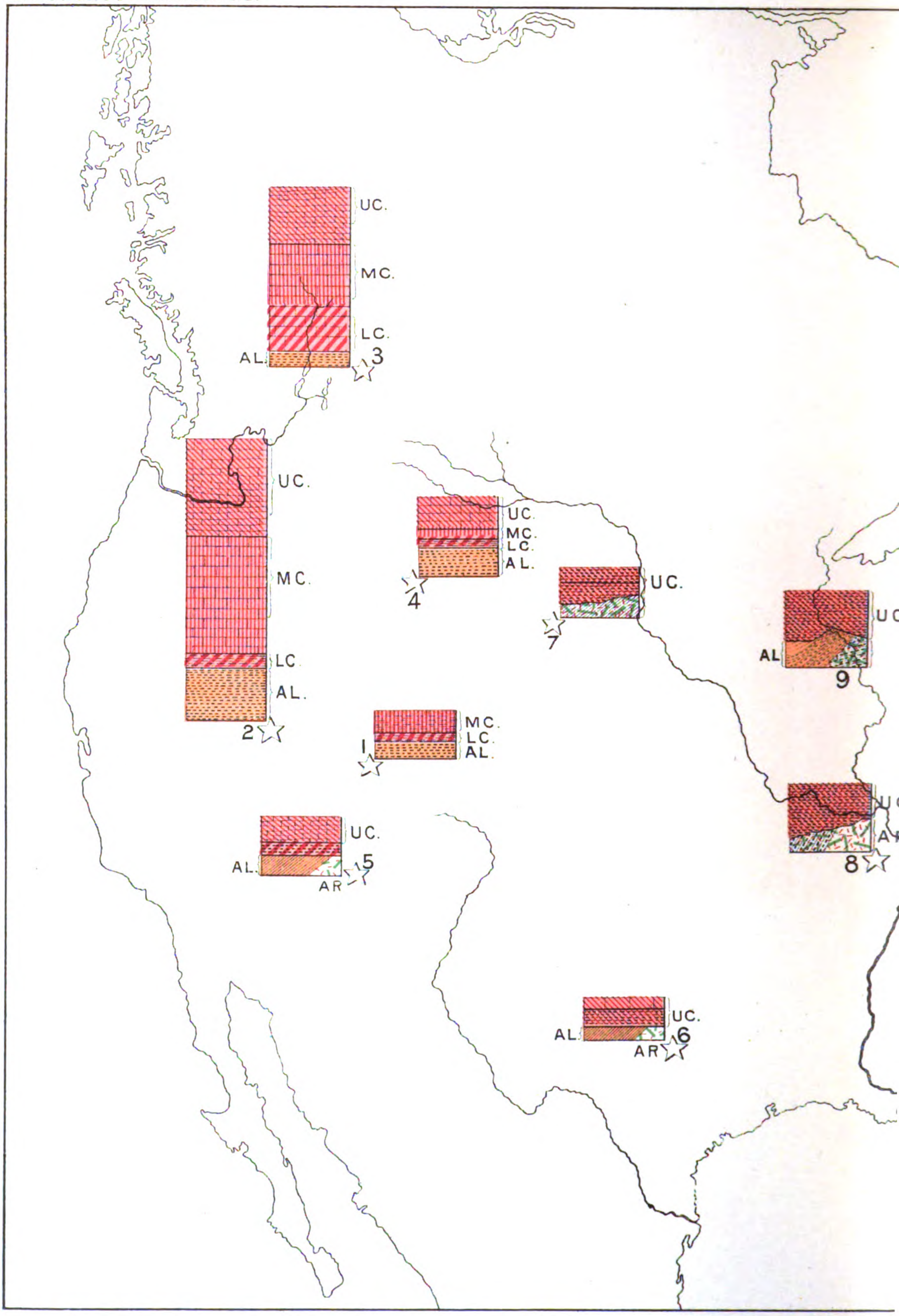
1. Western slope of the Wasatch Mountains. In this section the Cambrian rocks are conformably superjacent to the Algonkian. (See Fig. 46, p. 552.)
2. Eureka district of central Nevada. In this section the Algonkian and Lower Cambrian strata are conformable to each other. (See Fig. 45, p. 551.)
3. Mount Stephen section of British Columbia. The relations of the strata in this section are the same as in the Eureka section. (See Fig. 47, p, 552.)
4. Section on the Gallatin River, near Gallatin City, Mont. This is essentially the same as the Mount Stephen section, in having the Cambrian conformably superjacent to the Algonkian.
5. Grand Cañon of the Colorado, northern Arizona. In this section the Cambrian strata are unconformably superjacent to the inclined strata of the Algonkian. (See Fig. 48, p. 553.)
6. Llano County, Texas. This section is similar to that of the Grand Cañon, in having an unconformity between the Algonkian and the Cambrian.[1] (See Fig. 49, p. 554.)

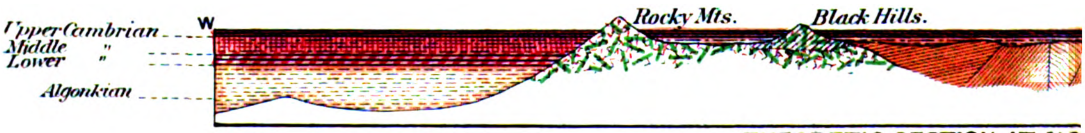
[1] Prof. T. B. Comstock has recently stated that Archean rocks also occur in the Texas area, subjacent to the Cambrian. (First Ann. Rep. Geol. Survey Texas, 1890, pp. 254–282.)

7. Black Hills of Dakota. The Upper Cambrian rests unconformably upon the Archean. (See Figs. 53 and 54, p. 561.)
8. Ozark Mountains, southeastern Missouri. The relations of the Cambrian to the Archean are the same as those in the Black Hills section.
9. Wisconsin and Minnesota. This is a generalized section to show the unconformity between the Upper Cambrian sandstone and the subjacent Archean and Algonkian rocks. (See Pl. XLV, Fig. 55, p. 561.)
10. Eastern Tennessee section. The Middle Cambrian zone is put in mainly on data from the northern Alabama section. The limits of the Lower Cambrian are not yet defined, but it is supposed to rest conformably upon the Algonkian rocks.
11. Eastern and northern slope of the Adirondack Mountains of New York. In this section the Potsdam sandstone of the Upper Cambrian rests unconformably upon and against the rocks of the Archean and Algonkian.
12. Trough between the Adirondack and Green Mountains, eastern New York and western Vermont. The base of this section is a massive limestone. Its contact with the subjacent rocks is unknown. Further details will undoubtedly change this section more or less. It has a great thickness, but the relations of the masses of limestone and shales, in the central portion of it, have not yet been fully worked out. (See Fig. 50, p. 555.)
13. North Attleborough and Braintree. In this section I have combined the Lower Cambrian of North Attleborough and the Middle Cambrian of Braintree in one generalized section to show their unconformity to the subjacent Archean.
14. Vicinity of St. John, New Brunswick. This section illustrates the unconformity between the Archean and the Cambrian and the shaly character of the Cambrian strata.
15. L'Anse au Loup, on the north side of the Straits of Belle Isle, Labrador. This section, like 13 and 14, represents the unconformity between the Cambrian and Archean.
16. Conception Bay, Avalon Peninsula. Newfoundland. The Cambrian rocks of the Avalon Peninsula rest unconformably upon strata of Archean and Algonkian age, as represented in the section. (See Fig. 51, p. 556.)

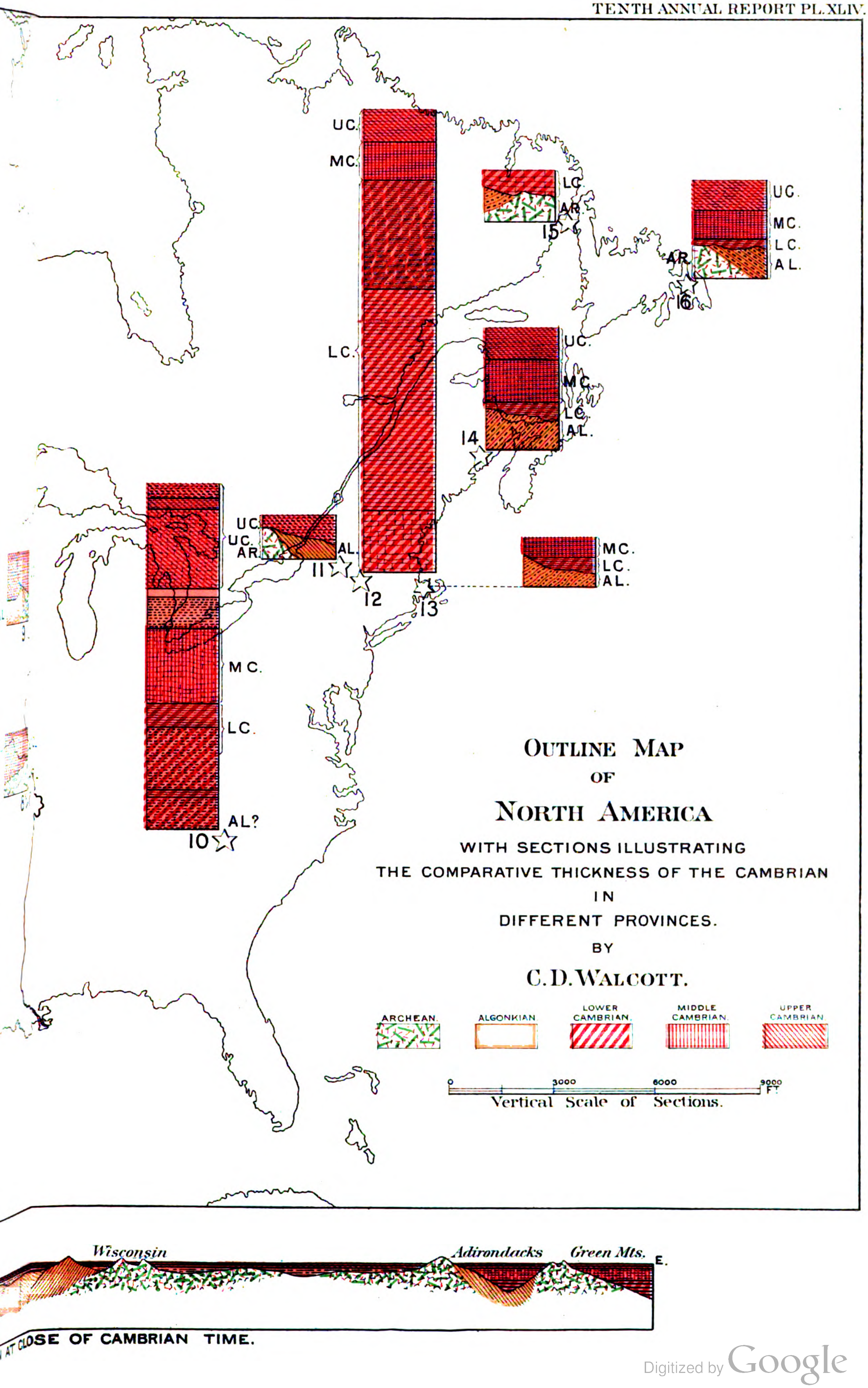
The theoretic section crosses the North American continent north of the 39th parallel in such manner as to traverse the Cambrian, Algonkian, and Archean at the close of the deposition of the sediments now forming the Upper Cambrian. The surface of the ancient continent is outlined by the line beneath the Cambrian deposit. The Upper Cambrian is represented as extending entirely across the continent, while the Middlė and Lower are fully developed only on the margins. In Wisconsin and east of the Adirondack Mountains the Algonkian rocks are unconformably subjacent to the Cambrian strata, while in Utah, Nevada, and British Columbia they are conformably beneath the Lower Cambrian.

To more fully understand the actual relations of the Cambrian strata to the subjacent rocks, the reader is requested to examine the sections represented by Fig. 45, p. 551, Fig. 46, p. 552, Fig. 47, p. 552, where there is entire conformity between the Cambrian and pre-Cambrian strata; Fig. 48, p. 553 and Fig. 49, p. 554, that illustrate the unconformity between the Upper Cambrian and what I consider to be the youngest of the unconformable Algonkian rocks; Fig. 51, p. 556, which illustrates the unconformity between the two groups in the





THEORETIC SECTION AT CLO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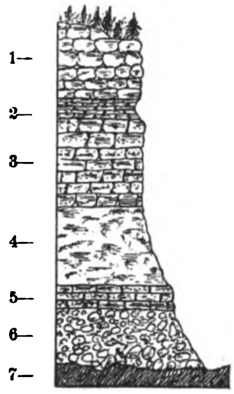
OUTLINE MAP
OF
NORTH AMERICA
WITH SECTIONS ILLUSTRATING
THE COMPARATIVE THICKNESS OF THE CAMBRIAN
IN
DIFFERENT PROVINCES.
BY
C. D. WALCOTT.
ARCHEAN.
ALGONKIAN.
LOWER CAMBRIAN.
MIDDLE CAMBRIAN.
UPPER CAMBRIAN.
0
3000
6000
9000 FT.
Vertical Scale of Sections.
Wisconsin
Adirondacks
Green Mts.
E.
AT CLOSE OF CAMBRIAN TIME.

Atlantic Coast Province. Over the interior of the continent their relations are shown by Figs. 53 and 54, where the Upper Cambrian



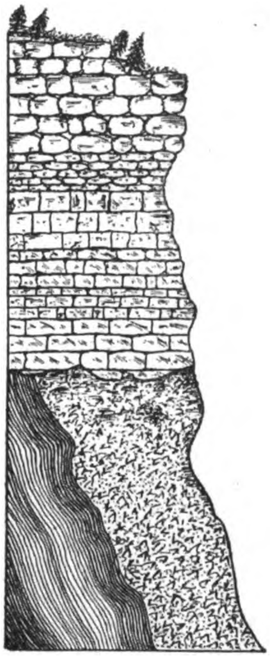


FIG. 53.—Section of the Upper Cambrian sandstone on Lower Rapid Creek, showing the conglomerate at the base and its unconformity with the subjacent Archean schists. 1. Massive gray limestone. 2. Thin-bedded impure limestone. 3. Reddish sandstone. 4. Concealed. 5. Coarse reddish sandstone. 6. Loose bowlders. 7. Schists. Numbers 1 and 2, Carboniferous; 3, 4, 5, and 6 Upper Cambrian.

FIG. 54.—Section of Upper Cambrian sandstone on Lower French Creek, showing the unconformity between it and the subjacent Archean rocks. (After Newton, Rep. Geol. and Resources Black Hills of Dakota, 1880, p. 90, Fig. 12.)

sandstones rest unconformably upon the upturned strata of the Algonkian or Archean, in the Black Hills of Dakota (7, of map, Pl. XLIV). In the Upper Mississippi Valley they are shown by Figs. 55–57, and Pls. XLV and XLVI. In Fig. 55 the Huronian quartzites

FIG. 55.—North and south sections through the Baraboo Ranges looking east. The section shows the horizontal Potsdam sandstone lying upon a deeply denuded surface of Huronian quartzite and quartz porphyry. (After Irving, Seventh Ann. Rep. U. S. Geological Survey, p. 405, Fig. 78.)

are seen to project up through the Potsdam sandstone. This is further illustrated by Prof. Chamberlin's theoretic restoration of the land surface in central Wisconsin, during the deposition of the Potsdam sandstone. In this section (Pl. XLV, a) the strata of the Archean, Huronian and Keweenaw series are shown to have formed the land surface from which the sediments forming the Potsdam sandstone

were derived. The other sections show the unconformity between the Potsdam sandstone and the subjacent rocks. Figs. 56 and 57

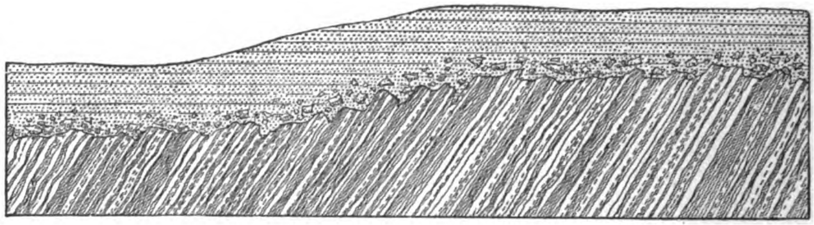


FIG. 56.—Section near Norway, Mich., showing the Potsdam sandstone overlying the ferruginous schists and ore of the Huronian or iron bearing series. (After Irving, Seventh Ann. Rep. U. S. Geological Survey, p. 410, Fig. 85.)

further illustrate the origin of the material forming the Potsdam sandstone, and Fig. 55 and Pl. XLV, fig. 1, prove that as the sea advanced upon the land the higher points of the Keweenawan continent continued to project above it as islands, and on the north as

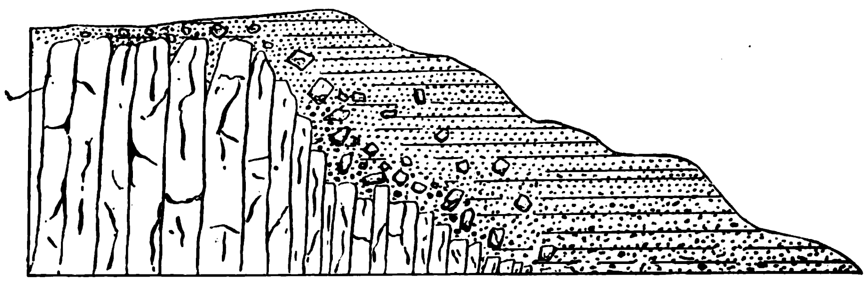


FIG. 57. Contact of the Huronian quartzite and Potsdam sandstone. South end of cliff on the east side of the upper Narrows of the Baraboo River near Ableman, Wis. Scale 50 feet to the inch. (After Irving, Seventh Ann. Rep. U. S. Geological Survey, p. 404, Fig. 76.

the great Archean nucleus of the continent during Upper Cambrian time. Around the islands, large and small, and along the shores of the northern continental mass, the sands, clays, etc., accumulated that now form the widely distributed sandstones and shales of the Upper Cambrian.

DESCRIPTION OF PLATE XLV.

1, Vertical section across northern central Wisconsin during the deposition of the Upper Cambrian (Potsdam) sandstone. (After Chamberlin, Geology of Wisconsin, vol. 1, 1883, Pl. 5, section.)

2, Section displayed to view on the east side of the gorge at the upper Narrows of the Baraboo River, showing the unconformity between the Potsdam sandstone and the subjacent Huronian quartzite. (After Irving, Seventh Ann. Rep. U. S. Geological Survey, p. 407, Fig. 80.)

3, Section on Black River in the vicinity of Black River Falls, Wis., showing the Potsdam sandstone resting on an eroded surface composed of granite and steeply inclined layers of gneiss and ferruginous schists. Scale 2 miles to the inch. (After Irving, Seventh Ann. Rep. U. S. Geological Survey, p. 403, Fig. 75.)

4, Section from southeast to northwest in the St. Croix River region of northwestern Wisconsin, through the Keweenaw series and Potsdam sandstone. (After Irving, Seventh Ann. Rep. U. S. Geological Survey, p. 413, Fig. 88.)

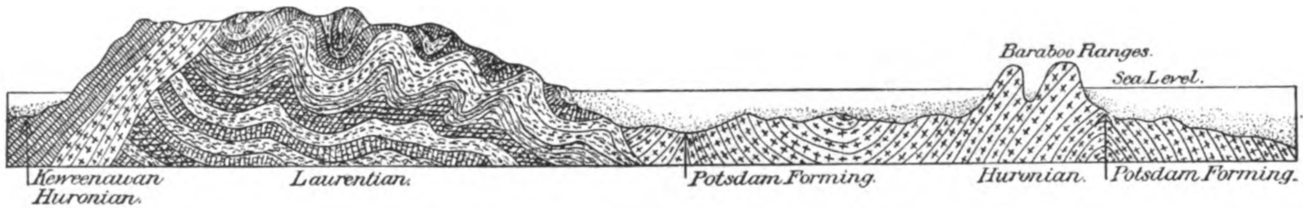


Fig. 1.

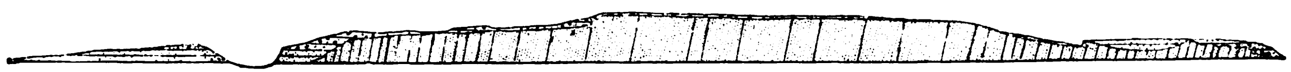


Fig. 2.

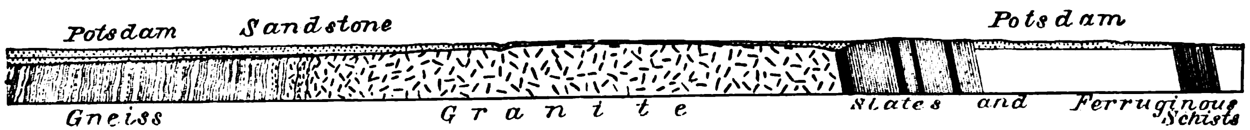


Fig. 3.

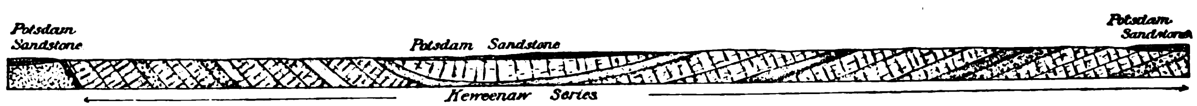


Fig. 4.

SECTIONS SHOWING DEPOSITION OF POTSDAM SANDSTONE IN WISCONSIN.

The study and correlations of the sections represented on the map have led to the construction of the theoretic section beneath it (Pl. XLIV). In this the lower portion of the great thickness of strata west of the Rocky Mountains is referred to the Algonkian system and the remaining portions to the three divisions of the Cambrian. From the Rocky Mountains to the Black Hills the Upper Cambrian is alone recognized, and from the Black Hills to the Upper Mississippi or Wisconsin area the Upper Cambrian, and from Wisconsin to the Adirondack Mountains of New York there is only the record of the presence of Upper Cambrian strata. East of the Adirondack Mountains, in the deep trough between them and the Green Mountains, a great thickness of Cambrian sediment accumulated. East of the Green Mountains the Lower and Middle Cambrian are known on the Atlantic coast; and it is assumed that the Upper Cambrian has been removed by erosion. Little attention has been given to the relative proportion of the vertical and horizontal scale; both are distorted in the section.

The study of the data given on Pl. XLIV and in the accompanying section leads to the conclusion that during the period of erosion of the Algonkian and Archean rocks of the interior of the continent prior to the deposition of the Upper Cambrian strata over them, the continent stood at a relatively high elevation above the sea into which the sediments were being washed. This is proved by the accumulation of more than 10,000 feet[1] of detrital sediment on the western shore during the latter part of Algonkian time; also by the great thickness of Lower and Middle Cambrian strata on both the eastern and western sides of the continent and the absence of these rocks from over the interior of the continent. It is readily inferred that the sediments washed from it on the eastern and western sides subsequently formed the Middle and Lower Cambrian rocks, the conformable pre-Cambrian rocks of the Wasatch Mountains and similar sections of strata to the north and south. The absence of strata of Upper Cambrian age in the Wasatch section (Fig. 46, p. 552) establishes the fact that the downward movement of the continent was not entirely uniform; and it is very probable that the accumulation of data from more extended observations will show other irregularities in the continental movement. As a whole, however, the elevation and depression of the continent appears to have been very uniform all across the central portion. That the Upper Cambrian sea was transcontinental is shown by the presence of the same species of Upper Cambrian fossils in similar stratigraphic relations to strata containing the Ordovician fauna in the valleys of the St. Lawrence and Lake Champlain and on the slopes of the Adirondacks of New York; in the southern Appalachian region of Tennessee and Alabama; in the Upper Mississippi Valley; in Wisconsin and Minne-

[1] Wasatch and Nevada sections.

sota; in the sandstones and limestones of Texas and the Black Hills of Dakota, and in the limestones of Nevada and Montana. It is not possible to demonstrate that the faunas in these widely separated localities were contemporaneous. We know that they have the same general stratigraphic relations to the superjacent faunas and to the subjacent faunas when the latter are present. The study of the Olenellus fauna also proves that it contains a similar assemblage of forms on the opposite sides of the continent, and that it is subjacent to a definitely marked Middle Cambrian fauna in Nevada, Utah, British Columbia, and New York, and that the Paradoxides fauna is superjacent to it in Newfoundland and Scandinavia.

It is exceedingly difficult to restore the topography of the North American continent at any comparatively recent geologic period, and it is doubly so for the ancient pre-Cambrian continent, as the sum total of what is not known so far exceeds that which is known. The new lines of thought and investigation opened up by such a study are often valuable in leading to results not anticipated, and often a strong working hypothesis or even a theory may result from the direct investigation. Such is, I think, the result of the present study of the condition of the continent in Cambrian time. This presentation of results is more or less tentative and incomplete, suggestive rather than decisive, but it will lead to the study of phenomena bearing upon the subject in a new light, and thus prepare the way for a fuller consideration of it in the future.

VII.—THE CONTINENT OF EUROPE DURING THE DEPOSITION OF THE SEDIMENT NOW FORMING THE OLENELLUS ZONE.

An outline map of Europe, showing the comparative thickness and depth of the deposition of the Cambrian and Lower Silurian rocks in different areas, prepared and published by Dr. Henry Hicks,[1] exhibits very clearly the view expressed by him that the sediments of the Cambrian and Silurian were largely deposited on the western side of the continent. In Spain and Wales the sediments accumulated to a great thickness. To the eastward, in Sardinia, Bohemia, and Scandinavia, the sections show less than one-half the thickness, and in central Russia they are still further reduced. East of the White Sea, on the Arctic coast, and in the Ural Mountains the deposits are very thin, including only some members of the Silurian that rest unconformably upon the Archean. That I may not misinterpret Dr. Hicks's views to the reader, a copy of his map is here introduced (Pl. XLVIII.) On the plate the Lower Cambrian occurs at the base of section B in Wales; also at the base of section E in Scandinavia and section F in Russia. The Middle Cambrian zone is known to occur in sections A, C, and D, as well as in sections B and

[1] Quart. Jour. Geol. Soc., vol. 31, 1875, pl. 27.

UNCONFORMITY BETWEEN POTSDAM SANDSTONE AND FERRUGINOUS SCHISTS.

E, and it is quite probable that the Lower Cambrian fauna is present in section A. To further illustrate the unconformity between the Archean and the Cambrian, illustrations of a section in Wales and one in Norway are introduced. (Figs. 58 and 59.)

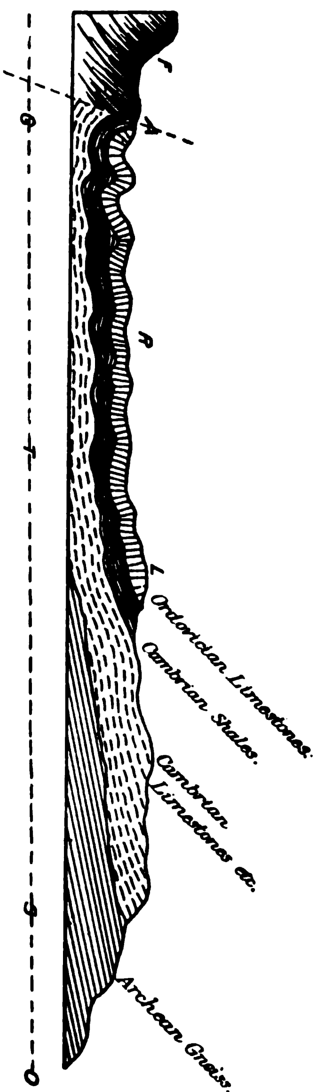


FIG. 59.—North and south section through the Dokka Valley, Torpen and Land, etc. Central Norway. (After Kjerulf.)

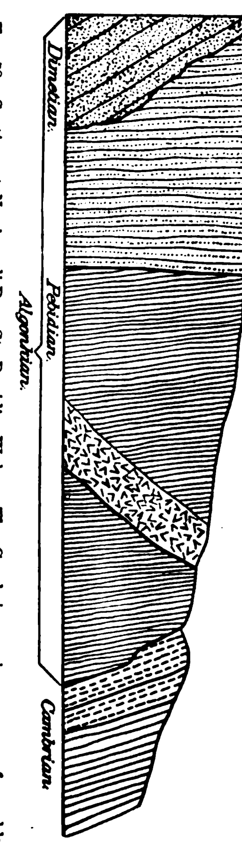


FIG. 58.—Section at Nun's-well Bay, St. David's, Wales. The Cambrian rocks are unconformably superjacent to the Pebidian strata of the Algonkian. (After Hicks, Quart. Jour. Geol. Soc., vol. 33, p. 236.)

It is evident from the facts presented in Dr. Hicks's map that the strata of the Cambrian were deposited upon a gradually sinking coast line, and that the greatest depression was on the western margin of the continent. The study of the sections containing the Olenellus or Lower Cambrian fauna indicates that the central portions of the continent, Bohemia, etc., were not depressed to the sea-

level until after the deposition of the Lower Cambrian. This leads to the conclusion that the movement which depressed the North American continent during Cambrian and Ordovician time also affected the western side of the European continent with a gradually diminishing force, from the Atlantic coast to the Ural Mountains.

VIII.—GEOGRAPHIC DISTRIBUTION.

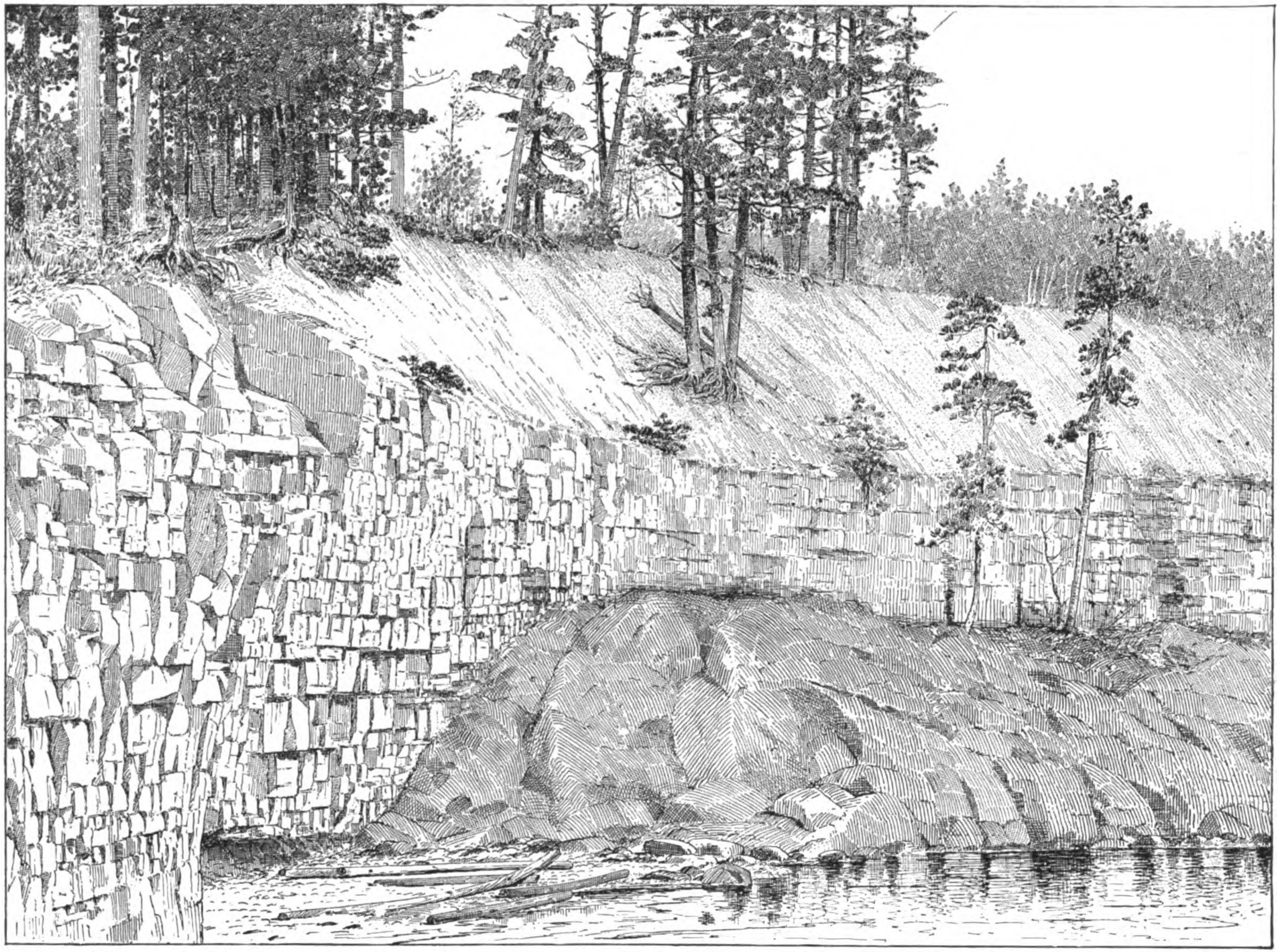
The geographic distribution of the strata containing the Olenellus fauna has already been outlined in section V, p. 549. For convenience of reference the American localities of occurrence may be grouped in three principal provinces or areas: First, the Atlantic Coast Province; second, the eastern border or Champlain-Hudson Province; third, the western border or Rocky Mountain Province.

THE ATLANTIC COAST PROVINCE.

The most northern area included in this province is that of the coast of Labrador on the Straits of Belle Isle. It extends along the coast for several miles and the section includes 231 feet of arenaceous beds resting on the Archean and subjacent to 143 feet of gray, reddish, and greenish limestones, in which abundant remains of fossils occur. The species known are: *Spirocyathus atlanticus*, *Coscinocyathus billingsi*, *Archæocyathus profundus*, *Planolites virgatus*, *Helminthoidichnites marinus*, *Scolithus linearis*, *Iphidea bella*, *Kutorgina cingulata*, *K. labradorica*, *Obolella chromatica*, *Orthisina*, ? sp. undet., *Orthisina* sp. ?, *Stenotheca ? elongata*, *S. ? rugosa*, *Hyolithes billingsi*, *Salterella pulchella*, *S. rugosa*, *Olenellus thompsoni* ?, *Ptychoparia miser*, *Protypus senectus*, *Solenopleura nana* ?.

Sir William E. Logan mentions the occurrence of the Olenellus fauna at Bonne Bay, on the northwestern coast of Newfoundland,[1] citing several species identical with those found on the coast of Labrador. Owing to the collector having included Lower Ordovician fossils in the same lot with the Olenellus, etc., a doubt remains as to the stratigraphic position of the beds from which the latter came. On the Atlantic side of Newfoundland fragments of a species of Olenellus were found in White Bay, according to Logan, but it was not until the writer studied the sections about Conception Bay that the fauna was well recognized. At Topsail Head a band of compact, gray and pinkish colored limestone is subjacent to about 100 feet of greenish argillaceous shales. The fauna in the limestone includes: *Kutorgina labradorica*, *Obolella atlantica*, *Scenella reticulata*, *Hyolithes impar*, *H. princeps*, *Hyolithellus micans*, *H. micans*, var. *rugosa*, *Microdiscus bellimarginatus*, *Olenellus* (*Mesonacis*) *bröggeri*, *Avalonia manuelensis*, *Agraulos strenuus*, *Solenopleura bombifrons*. On the opposite side of the bay, at Brigus Head, a

[1] Geol. Survey, Canada; Rep. Prog. from its commencement to 1863, pp. 865, 867.



UNCONFORMITY BETWEEN POTSDAM SANDSTONE AND ARCHEAN GRANITE.

bed of sandstone occurs beneath a limestone carrying *Olenellus* (*M.*) *bröggeri*, and the limestone is divided into three bands, by beds of shale, and the red and green shales extend several hundred feet upward in the section above the limestone. The strata of this portion of the province, however, are best seen in the Manuel's Brook section, west of Topsail Head (Fig. 51, p. 556), where a coarse, basal conglomerate rests conformably upon the Archean and is conformably subjacent to a series of red and green argillaceous shales that, in turn, are subjacent to dark argillaceous shales carrying the Paradoxides fauna. The fossils are most abundant in an impure arenaceous limestone which rests on the conglomerate, although quite abundant in the associated reddish shales. In the limestone and shales the following species were found: *Obolella atlantica, Helenia bella, Scenella reticulata, Stenotheca ? rugosa, S. ? rugosa*, var. *acutacosta, S. ? rugosa* var. *erecta, S. ? rugosa* var. *levis, S. ? rugosa* var. *paupera, Platyceras primævum, Hyolithes impar, H. princeps, H. quadricostatus, H. similis, H. terranovicus, Hyolithellus micans, Coleoloides typicalis Microdiscus helena, M. bellimarginatus, Olenellus* (*Mesonacis*) *bröggeri, Avalonia manuelensis, Ptychoparia ? attleboroughensis, Agraulos* (*S.*) *strenuus, A.* (*S.*) *strenuus* var. *nasutus, Solenopleura bombifrons, S. harveyi, S. howleyi.* Mr. E. Billings described *Straparollina remota* and *Hyolithes excellens* from a red limestone at Smith's Sound, Trinity Bay, that Mr. Murray correlated with the Brigus Head limestone. *H. excellens* appears to be identical with *H. princeps.*

The presence of the Lower Cambrian or Olenellus fauna in New Brunswick is claimed by Mr. Matthew. The evidence for this is presented in his latest paper on "Cambrian organisms in Acadia."[1] The section of the strata referred to the Basal series or pre-Paradoxides zone at the typical locality at Hanford Brook, St. Martin's, is as as follows:

		Thickness in feet.
"1.—*a.*	Coarse purplish red conglomerate resting on an amygdaloidal greenstone (toadstone) of the Coldbrook group	60
b.	Gray and purplish flags and sandstones with worm-casts, sea-weeds (Palæochorda and Buthotrephis), and numerous spicules of sponges.	70
c.	Purplish red sandstones, with greenish layers; remains of sea-weeds (Phycoidella), animal tracks (Psammichnites and Helminthites), worm-burrows (Arenicolites), etc	240
"2.—*a.*	Purplish red conglomerate, more friable than 1, *a*	35
b.	Soft purplish red shales, with green glauconite grains, the upper part firmer and more sandy, greenish gray layers interspersed especially towards the base. Platysolenites, Obolus, Volborthella, etc	175
c.	Purplish sandy shales, with a few bands of greenish shale; worm-casts (Scolites)	300
	Measures concealed, probably of this series	320
		1,200

[1] Trans. Roy. Soc. Canada, vol. 7, 1890, sec. 4, pp. 135-162.

"In this series of one thousand or more feet of beds, the very oldest layers which are fine enough to preserve organic markings, have trails and casts of marine worms, and also contain sea-weeds, one a Palæochorda or allied genus, the other a weed with a flat frond similar to Buthotrephis. That these beds are marine is clearly shown by the great numbers of spicules or hexactinellid sponges which they contain.

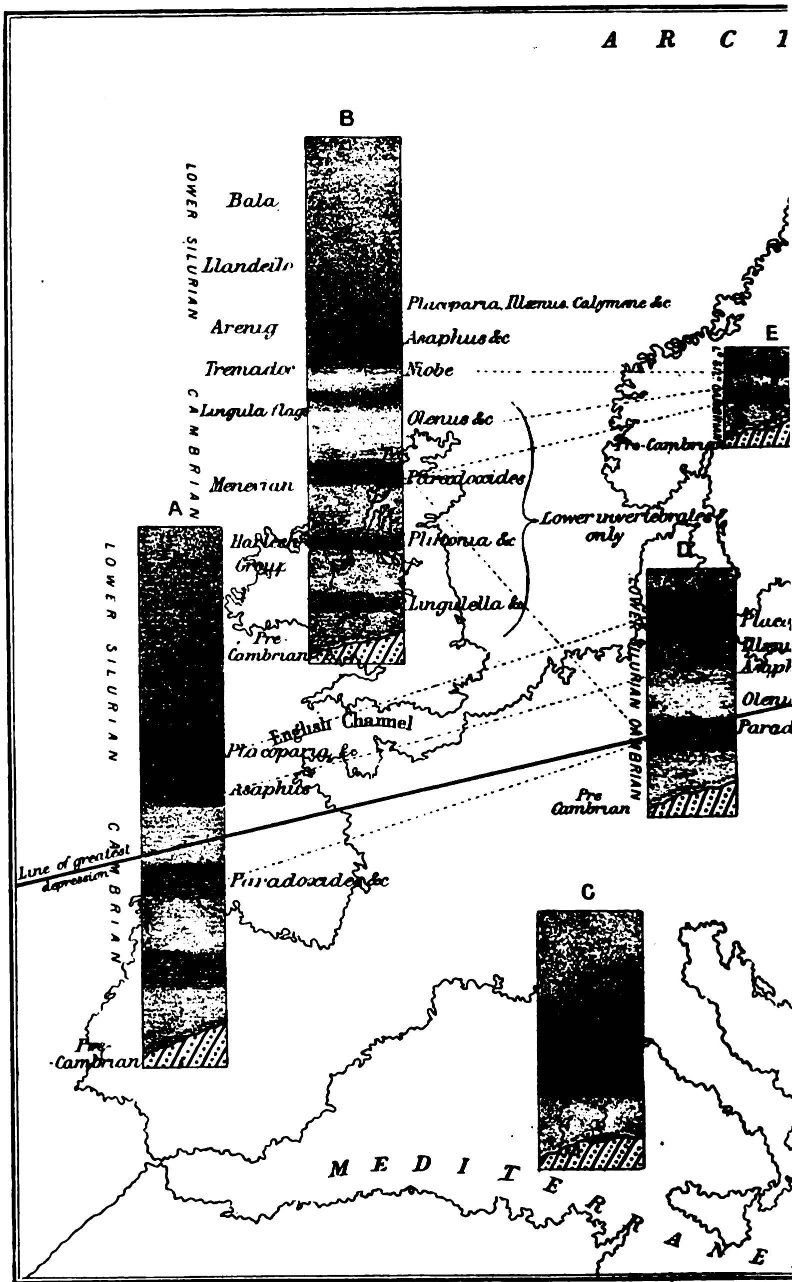
"About three hundred and fifty feet above the base, where the measures are flaggy, tracks of annelids are again abundant. Besides the smaller trails and burrows, there are frequent tracks of a marine animal, possibly a worm, similar to the markings on the Fucoidal sandstone of Sweden, which, by Prof. O. Torrell, have been referred to the genus psammichnites. A very similar track, with corresponding casts, occurs on the surfaces of the purple-streaked sandstones (Assise 3) of Band *b* in Division 1 of the St. John group, and a similar trail occurs as high up as the lower Band of Division 2 of that group. Above this point, such markings have not been found, though the kind of rock—flags and slates—is favorable to their occurrence. The flags of the middle of Division 2 of the St. John group seem to be the horizon of *Cruziana semiplicata* (Salter) and *C. similis* (Billings); but I have not found them here.

"About one hundred feet or more above the horizon where Psammichnites appears, separated from it by a conglomerate, indications of the Olenellus fauna show themselves. These consist of Volborthella (a chambered cell resembling Orthoceras), the cystidean genus Platysolenites, Pander, and a large Obolus, allied to *Michwitzia* (formerly *Obolus ?* or *Lingula ?*) *mon lifera* Linrs., of the Eophyton sandstone of Sweden and the upper part of the "Blue Clay" of Russia. Some of the layers in this part of the series abound in soft green grains similar to the glauconite grains of the Cambrian rocks in Russia. The paste enveloping them is red.

"A number of beds between this point and the top of the Basal series contain worm-casts and burrows, and some have remains of small strap-like sea-weeds." (Loc. cit., p. 138.)

"In summing up the facts bearing on the comparative age of this part of the Cambrian rocks in Acadia we get no aid from the typical genera of this horizon, Olenellus and Mesonacis, but the Acadian rocks contain other genera of this fauna which serve to fix their age with a certain degree of accuracy. Some of these genera, however, are such as may have a wider range of existence in time than the trilobites, and therefore are not of the same homotaxial value. The trilobites that do occur are not so definitive as some others." (Loc. cit., p. 143.)

If Mr. Matthew's stratigraphy be correct, this series is beneath the St. John group, although the absolute contact of the two formations has not been observed where the characteristic fossils of each occur



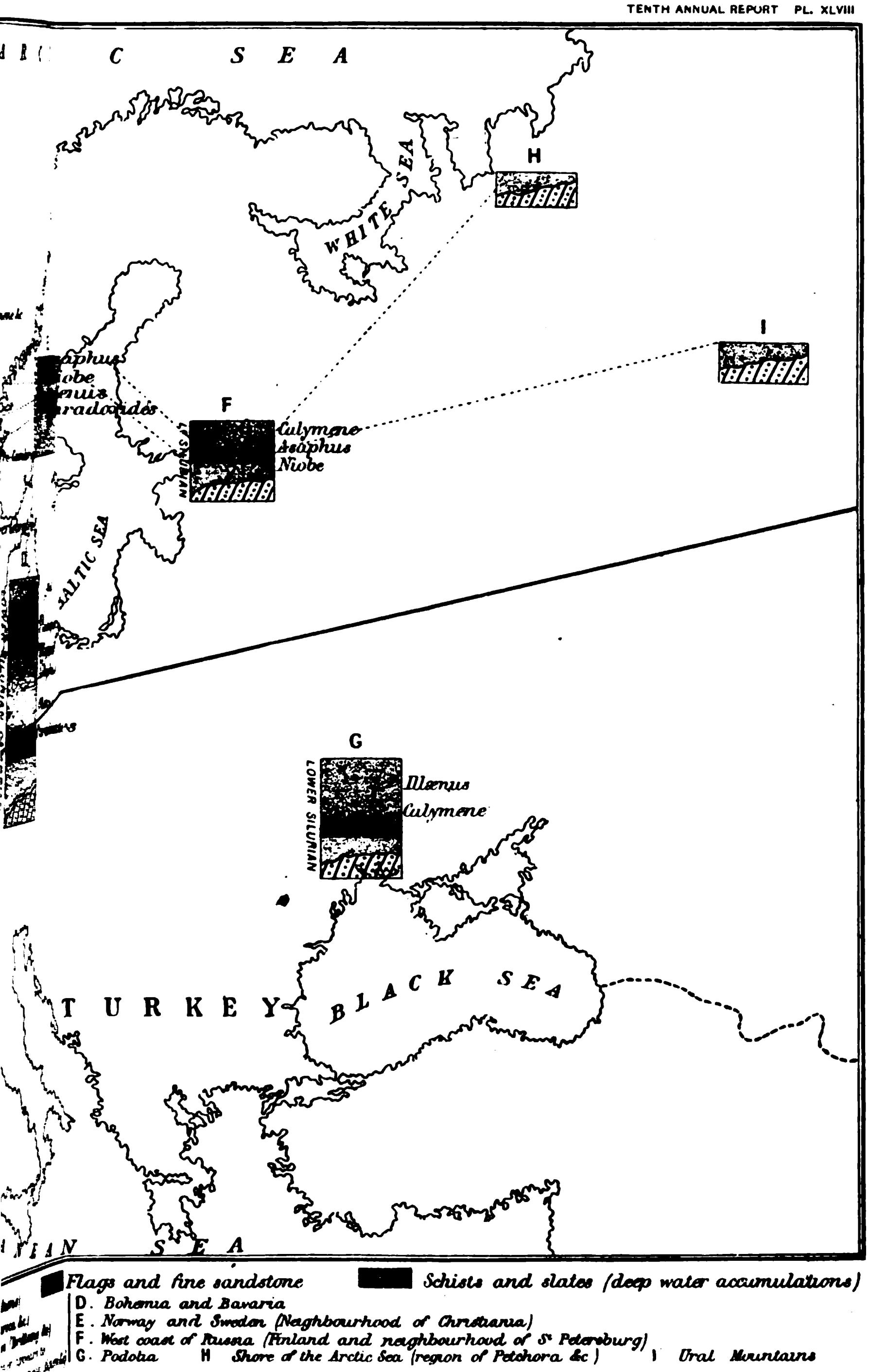
Conglomerates, Sandstones and Grits (shallow water accumulations)

A. Central regions of Spain (Guadarama, Montes de Toledo, provinces of Leon, Daroca &c)

B. Wales (North & South) For the most part this represents the succession also in France (Brittany &c

C. Sardinia. The succession here has not yet been thoroughly worked out, but this order appears to represent generally the conditions observed here, & also on the South Coast of the Mediterranean (Al

OUTLINE MAP OF EUROPE, SHOWING THE COMPARATIVE THICKNESS AND DEPT



DEPOSITION OF THE CAMBRIAN AND LOWER SILURIAN ROCKS IN DIFFERENT AREAS.

in the section. The Basal series rests unconformably upon the "Laurentian" rocks, and the relations of the portions of the sections to each other are well shown in the illustration of the sections on page 139. A portion of this section is also seen on Caton's Island, and this is described and illustrated by Mr. Matthew (loc. cit., pp. 140, 141). On page 142 these two sections are correlated with those of the St. John City and Ratcliffe's Mill stream.

In correlating the several beds of the Lower Cambrian Mr. Matthew has followed the lithological characters of the beds, as the faunas are not sufficiently characteristic for comparison. Owing to this I have only considered the fauna of No. 1 *b* of the section (St. John group) of Hanford and Caton's Island as belonging to the Lower Cambrian. If the stratigraphy be correct in the Hanford Brook and Caton's Island section I think there is little question that the Lower Cambrian fauna is represented in the New Brunswick section. A list of all the species is given in Section IV. (Ante p. 546.)

At the locality discovered by Prof. N. S. Shaler, near North Attleborough,[1] in eastern Massachusetts, the rocks consist of thin-bedded shaly layers which pass into moderately thick, fine grained, greenish and red slates. Intermingled with these, in several levels, layers of conglomerate occur which are evidently derived from a not far distant shore-line. Specimens of the reddish calcareo-arenaceous fossil-bearing rock, from this locality and from Newfoundland, are lithologically identical; and a number of species are common to the two deposits. The fauna includes: *Obolella atlantica*, *O. crassa*, *Fordilla troyensis*, Lamellibranch? (genus? and species?), *Scenella reticulata*, *Stenotheca ? curvirostra*, *S.? rugosa*, *S.? rugosa* var. *abrupta*, *S.? rugosa* var. *paupera*, *Pleurotomaria* (*Raphistoma*) *attleboroughensis*, *Hyolithes americanus*, *H. billingsi*, *H. communis* var. *emmonsi*, *H. princeps*, *H. quadricostatus*, *Hyolithellus micans*, *Salterella curvatus*, *Platyceras primævum*, *Microdiscus bellamarginatus*, *Olenellus walcotti*, *Ptychoparia ? attleboroughensis*, *Agraulos strenuus*.

Mr. Foerste found a species of Hyolithes at East Point, Nahant, Mass., which is identical with the species found near North Attleborough. He states that the Nahant limestones are represented by red slates near North Weymouth, and that it is probable that the red slates and included limestones underly the Middle Cambrian Paradoxides beds of Braintree.[2]

Mr. J. H. Sears, of the Peabody Academy of Science, at Salem, Mass., sent me a small collection of the fossils from East Point, Nahant, in May, 1890, and I identified *Hyolithes communis*, var. *emmonsi*, *Hyolithes princeps* Billings, and a finely corrugated tube

[1] On the Geology of the Cambrian district of Bristol County, Mass. Bull. Mus. Comp. Zool., Harvard College, vol. 16, pp. 13-26.

[2] Bost. Soc. Nat. Hist. Proc., vol. 24, 1889, pp. 261-263.

such as would result from cutting obliquely across the shell like that of the slender varieties of *Stenotheca rugosa.*

If we extend our observations of the strata to the eastern side of the Atlantic basin, we find that the Lower Cambrian (Bangor and Cærfai) series consist largely of green and purple slate, formed from a sediment almost identical with that of the Newfoundland section; and, further, that the shales or slates of the Paradoxides zone are lithologically the same in Newfoundland and Wales. In both cases the sediments were accumulated not far from a gradually sinking coast line, and they overlap on the subjacent Algonkian and Archean rocks.

CHAMPLAIN-HUDSON PROVINCE.

The sediments of the Olenellus zone, in this province, are largely developed in the trough lying between the Adirondack and Green Mountains. To the north, in the valley of the St. Lawrence, the deposit appears to have been mostly limestone, judging from the occurrence of the Olenellus fauna in bowlders of limestone in the conglomerates of Lower Ordovician age. From Bic Harbor, Trois Pistoles, and St. Simon the following species have been found in the conglomerate limestone, as observed in the collection of the Canadian Geological Survey and the Peter Redpath Museum of McGill College: *Trachyum vetustum, Scolithus linearis, Lingulella cœlata, Iphidea bella, Kutorgina cingulata, Obolella crassa, O. circe, O. gemma, Orthis, salemensis,* O. 1 n. sp., *Platyceras primævum, P. dawsoni, Scenella retusa, Stenotheca? rugosa, Hyolithes americanus, H. communis, H. princeps, Hyolithellus micans, Salterella pulchella, Microdiscus lobatus, M. speciosus, Olenellus thompsoni, Olenoides marcoui, Zacanthoides levis, Ptychoparia adamsi, P. metisensis, P. teucer, Ptychoparia* sp. undet., *Agraulos strenuus, A. redpathi, Protypus senectus, P. senectus* var. *parvulus.*

On the Island of Orleans, Dr. Selwyn found in the conglomerate limestone: *Obolella crassa, Orthisina* sp. ?, *Camerella* sp. ?, *Hyolithes americanus, Hyolithellus micans, Olenellus thompsoni, Ptychoparia adamsi, P. vulcanus, Solenopleura* sp. ? *Protypus senectus ? Olenoides marcoui, Zacanthoides levis.*

The origin of the bowlders containing the Olenellus fauna is unknown. There is a marked lithologic and paleontologic similarity between them and the limestone of Topsail Head and Conception Bay, Newfoundland, that points to similar conditions of sedimentation and life, and I found the head of an Olenellus on the Island of Orleans that is of the type of *O.* (*M.*) *bröggeri* of Newfoundland. It is quite possible that the deposits from which the conglomerates were derived extended around the Newfoundland coast, to the west and north, and thence along the margin of the pre-Cambrian land, southwest, toward the Adirondack Mountains of New York, and

that the disturbances toward the close of the Cambrian Period, in the St. Lawrence Valley, resulted in the uplifting of the Lower Cambrian strata and its denudation and breaking up during Upper Cambrian and Lower Ordovician time.

Sir William Dawson writes me that he considers that the conglomerates at Metis and St Simon are older than the Phyllograptus beds at Point Levis, and at Metis the associated shaly beds hold Retiolites, Linnarssonia, and Protospongia.

In northern Vermont a massive and more or less arenaceous dolomite occurs at the base of the Cambrian section, and the upper part of the Olenellus zone is formed of dark, arenaceo-argillaceous shales.[1] At the typical locality of Parker's quarry, in the township of Georgia, Franklin County, the following species have been found: *Leptomitus zitteli, Phyllograptus? cambrensis, Climacograptus?? emmonsi, Planolites congregatus, P. virgatus, Kutorgina cingulata, Orthisina festinata, O. orientalis, O.? transversa, Salterella pulchella, Protocaris marshi, Microdiscus parkeri, Olenellus thompsoni, O.* (*Mesonacis*) *vermontana, Olenoides? marcoui, Bathynotus holopyga, Ptychoparia adamsi, P. vulcanus, Protypus hitchcocki, P. senectus, P. senectus* var. *parvulus.* Near the boundary line between the United States and Canada, east of Highgate Springs, a number of species occur at the same relative horizon as at Parker's quarry,[2] all but two of which are found at the latter locality, viz: *Scenella? varians*, and *Ptychoparia teucer.* East of Swanton the fauna includes: *Kutorgina cingulata, K. labradorica* var. *swantonensis, Orthisina festinata, O. orientalis, Camerella? antiquata, Salterella pulchella, Olenellus thompsoni, Ptychoparia adamsi*, and *Protypus senectus.*

On the eastern side of the outcroppings of the strata of the Olenellus zone, in central and southern Vermont, the rock is a massive quartzite that was formed near the old pre-Cambrian shore-line. In this formation, near Bennington, Vt., *Scolithus linearis, Olenellus* sp. ? *Nothozoe vermontana*, and *Hyolithes communis* are found, and to the south, in Dutchess County, N. Y., at Stissing Mountain, *Olenellus* sp. ? and *Camerella? minor* occur in a similar sandstone.

In central Vermont the green and purple slates begin to appear in the Lower Cambrian, and in Washington County, N. Y., there are about 8,000 feet of green and purple slates that are identical in lithologic character with the slates of the Lower Cambrian in North Wales. Below the green and purple slates there is a great thickness of dark, argillaceous and, sometimes, arenaceous shales, in which the Olenellus fauna occurs. If lithologic characters could be relied upon, we might correlate the Lower Cambrian slates of Wales with the lower portion of the Cambrian section in Newfoundland and

[1] Bull. U. S. Geol. Survey, No. 30, 1886, pp. 15, 16. [2] Ibid., p, 18.

with the upper portion of the Olenellus zone in western Vermont and eastern New York. It is a striking coincidence that similar mechanical sediments should have been deposited in Wales, Newfoundland, eastern Massachusetts, eastern Vermont, and eastern New York, and also contain essentially the same fauna, with the exception of Wales, where the fauna is still almost unknown.

In Washington County, N. Y., the following named species have been found in the slates and interbedded limestones: *Protospongia* sp.?, *Archæocyathus* (*A*) *dwighti*, *Planolites annularius*, *Helminthoidichnites marinus*, *Lingulella cœlata*, *L. granvillensis*, *Lingulella* sp.?, *Linnarssonia sagittalis* var. *taconica*, *Orthis salemensis*, *Orthisina* sp.?, *Camerella?* sp.? *Fordilla troyensis*, *Modioloides prisca*, *Stenotheca? elongata*, *S.? rugosa*, *Hyolithes americanus*, *H. communis*, *H. impar*, *Hyolithellus micans*, *H. micans* var. *rugosa*, *Leperditia* (*I.*) *dermatoides*, *Aristozoe rotundata*, *A. troyensis*, *Agnostus desideratus*, *A.* sp.?, *Microdiscus connexus*. *M. lobatus*, *M. speciosus*, *Olenellus* (*Mesonacis*) *asaphoides*, *Olenoides fordi*, *Zacanthoides eatoni*, *Conocoryphe trilineata*, *C. reticulata*, *Ptychoparia? fitchi*, *Protypus? clavatus*, *Solenopleura? tumida*, and *S. nana*. In the vicinity of Troy, N. Y., the conglomerate and bedded limestone have afforded: *Archæocyathus* (*A.*) *rarum*, *A.* (*A.*) *rensselaericum*, *Planolites virgatus*, *Lingulella cœlata*, *Obolella crassa*, *Obolella gemma*, *O. nitida*, *Orthisina* sp.?, *Fordilla troyensis*, *Scenella retusa*, *Stenotheca? rugosa*, *Platyceras primævum*, *Hyolithes americanus*, *H. communis*, *H. communis* var. *emmonsi*, *H. impar*, *Hyolithes* 2 sp. undet., *Hyolithellus micans*, *H micans* var. *rugosa*, *Aristozoe troyensis*, *A.* sp.?, *Agnostus? nobilis*, *Microdiscus meeki*, *M. lobatus*, *M. speciosus*, *Olenellus* (*Mesonacis*) *asaphoides*, *Ptychoparia* sp.?, *Conocoryphe trilineata*, *Solenopleura nana*. South of Troy, in the northwest corner of Columbia County, N. Y., twelve of the above mentioned species have been found[1] in the brecciated limestones, and farther south, near Stockport, *Lingulella cœlata* and *Olenellus* sp.? occur in a brecciated limestone, interbedded in silicious shales.

The next occurrence of the fauna south of New York is in the clay shales resting on the quartzitic Chilhowee sandstone of Chilhowee Mountain, in eastern Tennessee. This locality has recently been discovered, and is yet to be developed. The fossils found are, Annelid trails in profusion, *Scolithus linearis*, Hyolithes, like *H. americanus*, *Isoxys chilhoweana*, and an undetermined species of Olenellus.

ROCKY MOUNTAIN PROVINCE.

In this province there appears to have been a large accumulation of more or less coarse, arenaceous sediment, commingled with con-

[1] Bull. U. S. Geol. Survey, No. 30, 1886, p. 27.

siderable argillaceous material, before the deposition of the sediments of the Olenellus zone. As far as known, the Olenellus fauna appeared at the time the character of the sediments was changing to finer sands and argillaceous clays, and then to calcareous clays. The sedimentation is unlike that of the sections on the eastern side of the continent. (See figures 45, p. 551, 46, and 47, p. 552.) The southern portion of the province is found in the Great Basin region of Utah and Nevada, between the Wasatch range and the Sierra Nevada range. In the eastern or Wasatch area *Linguella ella, Olenellus gilberti,* and *Cruziana* sp.? occur in a thin band of fine micaceous sandstone, about 200 feet from the summit of the Cambrian rocks, which are conformably subjacent to strata of Ordovician age. The Olenellus-bearing sandstones are covered with trails of annelids, etc., and are evidently a littoral or shore deposit.

In the Eureka district of central Nevada the fauna is confined to a narrow belt of arenaceous shales, with some intercalated limestone. The fauna consists of but seven species: *Girvanella ?* sp.? *Kutorgina prospectensis, Scenella conula, Olenellus gilberti, O. iddingsi, Olenoides quadriceps, Ptychoparia subcoronata,* and *Anomocare parvum.* Of these, two species, *Olenoides quadriceps* and *Scenella conula,* are found 500 feet higher up in the section.[1] In the Highland range section of Nevada the rocks are essentially of the same character as in the Eureka section; the two species, *Olenellus gilberti* and *O. iddingsi,* occur in an arenaceous shale associated with *Cruziana* sp.?.[2] In the Pioche section[3] more limestone is interbedded in the arenaceous shale and the fauna of the Olenellus zone is larger. It includes: *Eocystites?? Lingulella ella, Kutorgina pannula, Acrothele subsidua, Acrotreta gemma, Orthis highlandensis, Olenellus gilberti, Zacanthoides levis, Crepicephalus augusta, C. liliana,* and *Oryctocephalus primus.* Of these, *Kutorgina pannula, Acrothele subsidua, Acrotreta gemma,* and *Hyolithes billingsi* pass to the zone above that carrying Olenellus. In limestones of the Olenellus zone at Silver Peak, in western Nevada, the following species were collected by Mr. Clayton:[4] *Girvanella?* sp.?, *Spirocyathus atlanticus, Ethmophyllum meeki, E. whitneyi, Kutorgina cingulata?, Hyolithes princeps, Olenellus gilberti.*

In British Columbia the Lower Cambrian rocks occur on the eastern side of the Rocky Mountains. In the section of Mt. Stephen and Castle Mountain (fig. 47, p. 552), Mr. McConnell found the Olenellus fauna at the base of the Castle Mountain limestone; beneath it there are dark colored argillites and sandstones, estimated at over 10,000 feet in thickness.[5] They compare in position and character to the pre-

[1] Bull. U. S. Geol. Survey, No. 30, 1886, p. 32.
[2] Op. cit., pp. 33, 34. [3] Op. cit., p. 35. [4] Op. cit., p. 38.
[5] Geol. and Nat. Hist. Survey, Canada, Ann. Rep., new ser., vol. 2, 1887; Report on Geological Structure of a Portion of the Rocky Mountains, p. 29 D.

Olenellus strata, of the Wasatch section, which are referred to the Algonkian period. In the collection made by Mr. McConnell, from the limestones of the Olenellus zone, there are *Olenellus* sp.?, *Ptychoparia adamsi* and *Protypus senectus*.

The distribution of the genera and species is given in the following table, and, more or less, in discussing the relations of the Lower Cambrian fauna to that of the superjacent faunas. In the table the column under "Bic Harbor" also includes St. Simon, Trois Pistoles, Isle of Orleans, and any other associated localities in the St. Lawrence Valley. In the same manner the Pioche species are included under the Highland range column, and the Oquirrh Cañon, Utah, locality of *Olenellus gilberti* and *Lingulella ella* under the Wasatch Mountains column. The letters S. P., in the Highland range column, refer to the Silver Peak locality in western Nevada.

Table of the geographic distribution of the Lower Cambrian fauna in North America.

	Western Vermont.	Bic Harbor.	Labrador.	Newfoundland.	Eastern New York.	Eastern Massachusetts.	Eastern Tennessee.	Eureka, Nevada.	Highland Range.	Wasatch Mountains.	British Columbia.
SPONGIÆ.											
Leptomitus zitteli Walcott	×										
Trachyum vetustum Dawson		×									
Girvanella ? sp.?								×	S.P. ×		
Protospongia sp.?					×						
HYDROZOA.											
Phyllograptus ? cambrensis Walcott	×										
Climacograptus ?? emmonsi Walcott	×										
ACTINOZOA.											
Protopharetra sp.?											
Spirocyathus atlanticus Billings			×						S.P.		
Coscinocyathus billingsi Walcott			×								
Archæocyathus profundus Billings			×								
dwighti Walcott					×						
rarum Ford					×						
rensselæricum Ford					×						
Ethmophyllum meeki Walcott									S.P.		
whitneyi Meek									S.P.		
ECHINODERMATA.											
Eocystites ? sp.?									×		
TRAILS, BURROWS, AND TRACKS.											
Planolites annularius Walcott					×						
congregatus Billings	×										
virgatus Hall	×		×		×						
Helminthoidichnites marinus Emmons			×		×						
Scolithus linearis Hall (?)	×		×				×				
Cruziana sp.?									×	×	

Table of the geographic distribution of the Lower Cambrian fauna in North America—Continued.

	Western Vermont.	Bic Harbor.	Labrador.	Newfoundland.	Eastern New York.	Eastern Massachusetts.	Eastern Tennessee.	Eureka, Nevada.	Highland Range.	Wasatch Mountains.	British Columbia.
BRACHIOPODA.											
Lingulella cælata Hall (sp.)		×			×						
ella H. & W.									×	×	
granvillensis Walcott					×						
sp. ?					×						
Acrotreta gemma Billings									×		
Acrothele subsidua White									×		
Iphidea bella Billings		×	×								
Kutorgina cingulata Billings	×	×	×						S.P. ?		
labradorica Billings			×	×							
labradorica var. swantonensis Walcott	×										
pannula White (sp.)									×		
prospectensis Walcott								×			
sp. ?											
Linnarssonia sagittalis var. taconica Walcott					×						
Obolella atlantica Walcott				×		×					
chromatica Billings			×								
circe Billings		×									
crassa Hall (sp.)		×			×	×					
gemma Billings		×			×						
nitida Ford					×						
Orthis highlandensis Walcott									×		
salemensis Walcott		×			×						
Orthisina festinata Billings	×										
orientalis Whitfield	×										
? transversa Walcott	×										
? sp. undet		×	×								
sp. ?			×								
sp. ?					×						
Camerella ? antiquata Billings	×										
? minor Walcott					×						
? sp. ?		×			×						
LAMELLIBRANCHIATA.											
Fordilla troyensis Barrande					×	×					
Modioloides prisca Walcott					×						
Lamellibranch ?, genus ?, species ?						×					
GASTEROPODA.											
Helenia bella Walcott				×							
Scenella conula Walcott								×			
reticulata Billings				×		×					
retusa Ford		×			×						
? varians Walcott	×										
sp. ?											
Stenotheca ? elongata Walcott			×		×			* ×			
curvirostra S. & F.				×		×					

* 100 feet above the Olenellus zone.

Table of the geographic distribution of the Lower Cambrian fauna in North America—Continued.

	Western Vermont.	Bic Harbor.	Labrador.	Newfoundland.	Eastern New York.	Eastern Massachusetts.	Eastern Tennessee.	Eureka, Nevada.	Highland Range.	Wasatch Mountains.	British Columbia.
Stenotheca ? rugosa Hall (sp.)		×	×	×	×	×					
rugosa var. abrupta S. & F.						×					
rugosa var. acuta-costa n. var.				×							
rugosa var. erecta n. var.				×							
rugosa var. levis n. var.				×							
rugosa var. paupera Billings				×		×					
Platyceras primævum Billings		×		×	×	×					
dawsoni Walcott		×									
Straparollina remota Billings				×							
Pleurotomaria (Raphistoma) attleboroughensis S. & F.						×					
PTEROPODA.											
Coleoloides typicalis Walcott				×							
Hyolithes americanus Billings		×			×	×	×				
billingsi Walcott			×			×			*×		
communis Billings	×	×			×	×					
communis var. emmonsi Ford					×	×					
impar Ford				×	×						
princeps Billings		×		×		×			S.P.		
quadricostatus S. & F.				×		×		×			
similis Walcott				×							
terranovicus Walcott				×							
2 sp. (undetermined)					×						
Hyolithellus micans Billings		×		×	×	×					
micans var. rugosa Walcott				×	×						
Salterella curvatus S. & F.						×					
pulchella Billings	×	×	×								
rugosa Billings			×								
CRUSTACEA.											
Isoxys chilhoweana Walcott							×				
Leperditia (I.) dermatoides Walcott					×						
sp. undet.											
Aristozoe rotundata Walcott					×						
troyensis Ford					×						
sp. ?					×						
Nothozoe vermontana Whitfield	×										
Protocaris marshi Walcott	×										
TRILOBITA.											
Agnostus ? nobilis Ford					×						
desideratus Walcott					×						
sp. undet.					×						
Microdiscus connexus Walcott					×						
helena Walcott				×							
meeki Ford					×						
bellimarginatus S. & F.				×		×					

* 2,000 feet above the Olenellus zone.

Table of the geographic distribution of the Lower Cambrian fauna in North America—Continued.

	Western Vermont.	Bic Harbor.	Labrador.	Newfoundland.	Eastern New York.	Eastern Massachusetts.	Eastern Tennessee.	Eureka, Nevada.	Highland Range.	Wasatch Mountains.	British Columbia.
Microdiscus lobatus Hall		×			×						
speciosus Ford		×			×						
parkeri Walcott	×										
sp. ?											
Olenellus thompsoni Hall	×	×	?				?				
gilberti Meek								×	S.P. ×	×	× ?
iddingsi Walcott								×	×		
(Mesonacis) vermontana Hall (sp.)	×										
(Mesonacis) asaphoides Emmons (sp.)					×						
(Mesonacis) bröggeri Walcott				×							
walcotti S. & F.						×					
Olenoides fordi Walcott					×						
? marcoui Whitfield (sp.)	×	×									
quadriceps H. & W.								×			
Zacanthoides eatoni Walcott					×						
levis Walcott		×							×		
Bathynotus holopyga Hall	×										
Avalonia manuelensis Walcott				×							
Conocoryphe trilineata Emmons (sp.)		?			×						
reticulata Walcott					×						
Ptychoparia adamsi Billings	×	×									×
? attleboroughensis S. & F.				×		×					
? fitchi Walcott					×						
metisensis Walcott		×									
miser Billings (sp.)			×								
subcoronata H. & W.								×			
teucer Billings (sp.)	×	×									
vulcanus Billings (sp.)	×	×									
2 sp. ?		×			×						
Agraulos redpathi Walcott		×									
strenuus Billings		×		×		×					
(S.) strenuus var. nasutus Walcott				×							
Crepicephalus augusta Walcott									×		
liliana Walcott									×		
Oryctocephalus primus Walcott									×		
Anomocare parvum Walcott								×			
Protypus hitchcocki Whitfield (sp.)	×										
senectus Billings (sp.)	×	×	×								×
senectus var. parvulus Billings	×	×	×								
? clavatus Walcott					×						
Solenopleura bombifrons Matthew				×							
harveyi Walcott				×							
howleyi Walcott				×							
? tumida Walcott					×						
nana Ford			?		×						

In the following summary the total number of American genera and species are given under each class:

Résumé of American fauna.

	Number.		
	Genera.	Species.	Varieties.
Spongiæ	4	4	0
Hydrozoa	2	2	0
Actinozoa	5	9	0
Echinodermata	1	1	0
Trails, burrows, and tracks	4	6	0
Brachiopoda	10	29	2
Lamellibranchiata	3	3	0
Gasteropoda	6	13	5
Pteropoda	4	15	2
Crustacea	5	8	0
Trilobita	15	51	2
Total	59	141	11

The fauna referred to the Lower Cambrian by Mr. Matthew in New Brunswick has not been incorporated in the preceding tables, and it has not been illustrated, owing to the fact that the illustrations for this paper were completed before the publication of Mr. Matthew's memoir. He describes five new genera, Phycoidella, Microphycus, Monadites, Radiolarites, and Dichoplectella, and eighteen new species, *Phycoidella stichidifera*, *Palæochorda setacea*, *Hydrocytium ? silicula*, *Microphycus catenatus*, *Monadites globulosus*, *M. pyriformis*, *M. urceiformis*, *Radiolarites ovalis*, *Plocoscyphia ? perantiqua*, *Astrocladia ? elongata*, *A. ? elegans*, *A. ? virguloides*, *Dichoplectella irregularis*, *Hyalostella minima*, *Obolus ? major*, *Lingulella martinensis*, *Leperditia ventricosa*, and *L. steadi;* and illustrates five genera and five species—*Buthotrepis antiqua* Brongniart, *Platysolenites antiquissimus* Eichwald, *Volborthella tenuis* Schmidt, *Psammichnites gigas* Torrell, and *Arenicolites lyelli* Torrell var. *minor*—that he identifies with the Lower Cambrian fauna of Sweden, and proposes the genus *Holmia* for *Olenellus kjerulfi.*[1] He also mentions *Agraulos articephalus* and *Ellipsocephalus* sp. from 1*b* of the "St. John Group," p. 143, and *Obulus pulchea.*

If Mr. Matthew be correct in referring this fauna to the pre-Paradoxides zone we now have from America 67 genera, 165 species, and 12 varieties in the Lower Cambrian or pre-Paradoxides Cambrian fauna of North America.

It is yet uncertain how many identical species there may be

[1] Trans. Roy. Soc. Canada, vol. 7, sec. iv., pp. 135–162, 1890.

between America and Europe. Mr. Matthew has identified five. Omitting these and also the list of Torell's genera and species, applied to trails and annelid borings, there remain about eight genera and thirty species to account for from pre-Paradoxides Cambrian rocks. Adding these to the American fauna the totals are 75 genera and 195 species.

EUROPE.

The distribution of the fauna in Europe is confined to Scandinavia, Russia and Britain, with the exception of a single species somewhat doubtfully referred to the fauna from Spain and probably a portion of the Cambrian fauna of the Island of Sardinia.

Scandinavia.—From the work of the Swedish and Norwegian geologists it appears that in Scandinavia the Archean is subjacent to a considerable thickness of sandstone with intercalated shale, in which *Olenellus* (*H.*) *kjerulfi* and other fossils occur. The Olenellus appears near the summit of the series and just beneath strata in which Paradoxides is found. According to Holm[1], who is the latest authority on the subject, the fauna of the Olenellus zone in Scandinavia, consists of: *Olenellus* (*H.*) *kjerulfi* Linnarsson, *Ellipsocephalus nordenskioldi*, *Arionellus primævus* Brögger, *Hyolithes* sp. undet., *Metoptoma* sp., *Lingulella ? nathorsti* Linnrs., *Obolus* sp., *Discina ?* sp. From the Eophyton sandstone, beneath the *Olenellus* (*H.*) *kjerulfi* zone, Linnarsson described[2] *Astylospongia radiata*, Linnars., *Bythrotrephis* sp. *Aglecrinites lindstromi* Linnars., *Lingula ? monolifera* Linnrs., *Hyolithes levigatus* Linnars., *Arenicolites spiralis* Torell, *Fraena tenella* Linnars., *Cruziana dispar* Linnars., *Scolithus mirabilis* Linnars., *Eophyton linnæanum* Torell, *E. torelli* Linnars. These last three species are probably based on inorganic markings. In addition to the preceding, Dr. Torell described and illustrated, in 1868, *Arenicolites gigas* Torell *Scolithus linearis* "Hall," *Cordiates? nilssoni*, *Eophyton linnæanum* Torell and an undetermined form; he also described *Lingula* sp., *Fucoides antiquus*, *F. concinnatus* and *Paleophycus tubularis* Hall.[3]

In a later memoir he mentions a number of trails and borings from the sandstones at Lugnas, placing them under various genera and species. They include: *Cruziana dispar* Lins., sp., *Cruziana ? orbicularis* n. sp., *Lithodictyon fistulosum* n. gen. n. sp., *Palæophycus tubularis* Hall, *Fucoides antiquus* Brongn., *Fucoides circinnatus* Brongn., *Archæorrhiza tuberosa* n. gen. n. sp., *Halopoa* n. gen., *Halopoa imbricata* n. sp., *Halopoa composita* n. sp., *Cordaites ?*

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[1] Aftryck vr. geol. Fören. Stockholm Förhandl., vol. 9, part 7, 1887, p. 22.

[2] Geog. och Pal. Iakttag. öfver Eophytonsandstenen i Vestergötland. Kongl. Svenska Vet. Akad. Handl., vol. 9, No. 7, 1871.

[3] Sparagmitetagens geognosi och paleontologi. Acta Univer. Lundensis, Lunds Univer. Års-Skrift, vol. 4, 1868, pp. 34-39, pls. 1-3.

nilssoni Tor., *Eophyton linnæanum* Tor., *E. torelli* Linnars., *Psammichnites* n. gen., *P. gigas* Tor., *P. gumælii* n. sp., *P. impressus* n. sp., *P. filiformis* n. sp., *Protolyellia princeps* n. gen. n. sp., *Spatangopsis costata* n. gen. n. sp., *Micrapium erectum* n. gen. n. sp., *Spiroscolex* n. gen., *S. spiralis* n. sp., *S. crassus* n. sp., *Scolithus linearis* Hall, *S. errans* n. sp., *S. pusillu s* n. sp., *Monocraterion tentaculatum* n. gen. n. sp., *Diplocraterion* n. gen., *D. parallelum* n. sp., *D. lyelli* n. sp.[1] Without figures or specimens it is impossible to speak intelligently of these genera and species, as they are founded largely on trails, burrows, and casts of trails and markings on and in the sandstone.

In Sweden the strata of the Olenellus zone are everywhere conformably subjacent to the Paradoxides beds. They are almost exclusively sandstones except in the north of Sweden, where they contain considerable intercalated beds of schist. The zone is divided into Eophyton and Fucoid sandstones.[2] In Scania the series is divided into four zones, with a maximum thickness of 910 feet. The most interesting zone is that of the Lungas sandstone, from which the casts of the Medusæ, described by Nathorst,[3] were obtained.

The section, according to Dr. Lundgren,[4] is as follows:

(4) *Greywacke schists* (50 feet), containing nodules of phosphorite, but no recognizable fossils.

(3) *Hardeberga sandstone* (600 feet). A coarse grained, hard sandstone with quartzose matrix, passing into greywackes in the upper zones, containing fucoid-markings and burrows of Annelides.

(2) *Quartzite and quartzite conglomerate* (150 to 200 feet). A thick, hard rock, brittle, with conchoidal fracture.

(1) *Lugnas sandstone.* A coarse sandstone (60 feet), containing (crystals of) quartz, felspar, and mica; in other words, an *arkose.* According to Angelin himself, the lowest layers of this sandstone alternate with the bedded gneiss. According to Linnarsson, this relation is open to question.

According to Nathorst,[5] the section at Andrarum, in southwestern Sweden, is as follows, from below upward:

1. Sandstone with worm tracks; sandstone, pyritiferous.
2. Greywacke slate, with worm tracks and Lingula; greywacke, lime-bearing, with Lingula.
3. Drawing slate, with Lingula, Theca (rare).
4. Gray limestone, with fragments of fossils.

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[1] Petrificata Suecana Formationis Cambricæ. Acta. Univer. Lundensis. Lunds Univer. Ars-Skrift., 1870, vol. 6, pp. 1–14.

[2] A comparison between the oldest fossiliferous rocks of northern Europe; G. Linnarsson. Geol. Mag., new ser., decade 2, vol. 3, 1876, p. 146.

[3] Om Aftryck af Medusor i Sveriges Kambriska lager. Kongl. Sv. Vetenskaps-Akad. Handl., vol. 19, 1881, No. 1.

[4] Lundgren, Bernhard, text to Angelin's Geol. Öfversigts-Karta öfver Skåne, 1878, pp. 12–18.

[5] Om lagerföljden inom Cambriska formationen vid Andrarum i Skåne: Öfvers. Kongl. Vetenskaps-Akad Förhandl., No. 1, 1869, pp. 61–65.

5. Drawing slate, with Lingula and horizontal worm tracks.
6. Alum slate and swinestone, with Paradoxides, Agnostus, Microdiscus, Conocoryphe, Theca, Lingula. Graptolites.
7. Andrarum limestone, with the fossils enumerated before, in another place.
8. Alum slates and swinestone, with fossils in the following order: Olenus, Agnostus, Orthis, Parabolina, Eurycare, Leptoplastus, Sphæropthalmus, Peltura, Acerocare.

In central and northern Norway Professor Kjerulf divides the lower portion of the section into: 1*b*, the Lower Paradoxides zone, with *Paradoxides kjerulfi*, etc.; and 1*a*, the Sparagmite formation, without fossils.[1] The base of the section rests unconformably upon the Archean; and 1*b* is succeeded by the *Paradoxides tessini* beds.

The sections on Lake Miösen[2] and through Fugelberg and Ulven show the succession of strata to be as follows, from above downward:

Dark clay slates, with graptolites, near Ulven	Stage 3
Gray limestone, with Orthoceras, at Ringsaker	Stage 3
Black alum shales, with stink-stone and *Agnostus pisiformis*, at Nyhus	Stage 2
In the lowest alum shales, of considerable thickness, Linnarsson recognized *Agnostus parvifrons* Linnarsson, which belongs to a lower Palæozoic horizon	Stage 1c
Green clay slates, with occasional calcareous sandstone beds and *Olenellus* (*Paradoxides*) *kjerulfi* Linnarsson, Arionellus, Obolus, Discina, at Tomten	Stage 1*b*
Quartz sandstone, reddish and white, at Tomten	Stage 1*a*

Russia.—In Russia the Olenellus zone, according to Schmidt, occurs in Estland.[3] The relation of the strata to the section in Norway and Sweden is shown in the following scheme:

Scheme.

East Baltic region.	Swedish.	Norwegian.	
Dictyonema schist. Ungulite sand.	Dictyonema schist.	Dictyonema schist	2*e*
	Olenus zone.	Olenus zone	2*d* 2*c* 2*b* 2*a*
	Paradoxides zone.	Paradoxides zone	1*d* 1*c*
	Olenellus zone.		
	Zone of O. Kjerulfi.	Zone of O. Kjerulfi	1*b*
Fucoidal sandstone. Zone of O. Mickwitzi. Blue clay. Lower sandstone.	Fucoidal sandstone. Eophyton sandstone.	Sparagmite étage	1*a*

[1] Die Geologie des südlichen und mittleren Norwegen, Bonn., 1880, p. 155.
[2] Op cit., pp. 132–133.
[3] Ueber eine neuentdeckte untercambrische Fauna in Estland, Mém. Acad. Imp. Sci., St. Pétersbourg, ser. VII, vol. 36, No. 2, 1888, pp. 12, 13.

The correlations made in the scheme are of great value, as by them the Fucoidal and Eophyton sandstones of Sweden are clearly included in the Olenellus zone, and with them their included faunas. The list of fossils given by Dr. Schmidt includes *Olenellus mickwitzi* Schmidt, *Scenella discinoides* Schmidt, *S. ? tuberculata* Schmidt, *Mickwitzia monilifera* Linnarsson (sp.), *Obolella ?* sp., *Discina ?* sp. *Volborthella tenuis* Schmidt, *Platysolenites antiquissimus* Eichwald (sp.), *Medusites lindstromi* Linnarsson, *Frœna tenella* Linnarsson, Cruziana sp., Primitia ? (sp.). The genus Mickwitzia was proposed to include the *Lingula ? monolifera* of Linnarsson. For the details of the fauna and sedimentation the reader is referred to Dr. Schmidt's admirable memoir.

Spain.—The only species recorded from the Spanish peninsula that can be classed with the Olenellus fauna is *Ethmophyllum marinus* Rœmer.[1]

On the Island of Sardinia a large Cambrian fauna has been discovered that includes the genera Archæocyathus, Coscinocyathus, Obolella, Kutorgina, Olenopsis, Metadoxides, etc. Until more complete data is published on the geological section and the range of the species, it is not safe to assign any one group of species to the Olenellus zone. Dr. Bornemann, however, is now working on this fauna, and he may soon determine the stratigraphic range of the various genera and species, and thus differentiate between the Olenellus and Paradoxides faunas, unless they are commingled in the same stratum of rock.

Britain.—The Lower Cambrian strata of Britain are largely found in North and South Wales, although a small area in Shropshire has afforded the only specimens of Olenellus found in Britain. According to Dr. Hicks, the Cambrian rocks of St. David's, in South Wales, consist at the base of the Cærfai group, which is unconformably superjacent to the crystalline Archean rocks, and conformably subjacent to the Solva group, in which the Paradoxides fauna occurs. The Cærfai group includes, at St. David's, 1,570 feet of strata: conglomerates, 520 feet; red shales and schists, with fossils, 50 feet, and pebble sandstone, 1,000 feet. In the table the Bangor and Llanberis Lower Cambrian rocks of North Wales are included.[2] The fossils found by Dr. Hicks in the Lower Cambrian rocks of South Wales are: *Lingulella primæva, L. ferruginæ, Discina cærfaiensis, Leperditia ? cambriensis.*[3] These, with the species from North Wales, described by Dr. Henry Woodward[4] as *Conocoryphe viola*, do not

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[1] Lethæ a Geognostica, vol. 1, 1880.

[2] Classification of the Eozoic and Lower Palæozoic rocks of the British Isles. Pop. Sci. Rev., n. ser., vol. 5, 1881, pp. 289–308; one plate of sections.

[3] Quart. Jour. Geol. Soc., vol. 27, 1871, pp. 399–404.

[4] On the discovery of trilobites in the upper green (Cambrian) slates of Penrhyn, Bethesda, near Bangor, North Wales. Quart. Jour. Geol. Soc. London, vol. 44, 1888, pp. 74–78, pl. 4.

prove the presence of the Olenellus zone, but the weight of stratigraphic evidence is so strongly in favor of including them in its fauna that I shall do so. In the summer of 1888 I visited the locality of *Conocoryphe viola*, and found fragments of it associated with a species of Hyolithes. At the Cumley quarries, Little Caradoc, Shropshire, Professor Lapworth[1] discovered in some calcareous sandstone, interbedded in the Cumley sandstone, *Kutorgina* sp. ?, *Scenella* sp. ?, *Ptychoparia* sp. ?, *Obolella* sp. ?, *Hyolithellus* sp. ?, and *Olenellus* (*H.*)*callavei*.

France.—In a recent paper, M. A. Bigot[2] compares the Cambrian rocks of Wales with those of the northwest of France, in Bretagne and Normandie, and expresses the result in the following table.[3]

Wales.	Normandie.
Arenig.	Armorican sandstones.
Olenus.	Feldspathic sandstones.
Solva and Menevian.	Green schists and sandstones.
Cærfai.	Red schists and marbles.
Conglomerate.	Purple pudding-stone.
Pebidian.	Schists of Saint-Lô.

If the correlations in this table are correct it is not improbable that the Olenellus fauna will be found in the Red schists and marble, correlated with the Cærfai terrane.

As far as known the Olenellus fauna does not occur on the continents of Asia, Africa, Australia, or South America.

RELATIONS OF THE LOWER CAMBRIAN FAUNA TO THE SUPERJACENT FAUNAS.

The fauna succeeding the Olenellus fauna, in the stratigraphic succession, has usually been called the Paradoxides fauna, from the presence, in all the typical sections in the Atlantic Basin, of species of the genus Paradoxides. In the sections of Cambrian strata in the Rocky Mountain province and the Champlain-Hudson province, there is a Middle Cambrian fauna, more or less distinctly defined, that succeeds the Olenellus fauna, but it is not the typical Paradoxides fauna of the Atlantic province. On this account I will speak of the Middle Cambrian fauna, of the Atlantic Basin, as the Paradoxides fauna or Middle Cambrian fauna; and the term Middle Cambrian fauna will be applied equally to the Paradoxides fauna and to the fauna occupying the same stratigraphic position in the Champlain-Hudson and Rocky Mountain provinces.

[1] On the discovery of the Olenellus fauna in the Lower Cambrian rocks of Britain. Nature, vol. 39, 1888, pp. 212, 213.

[2] Le Précambrien et le Cambrien dans le Pays de Galles et leurs equivalents dans le massif Breton. Bull. Soc. géol. France, 3d ser., vol. 17, 1889, pp. 161–183.

[3] Op cit., p. 181.

PHYSICAL OR STRATIGRAPHIC RELATIONS.

The section on Manuel's Brook (Fig. 51, p. 554) shows a continuous deposition of sediments, from the basal conglomerate, through the Lower Cambrian (Olenellus fauna) time, to and through Middle Cambrian (Paradoxides zone) time; a thickness of about 250 feet of shale having been deposited between the typical Olenellus zone and the Paradoxides zone. The same conditions of continuous and conformable sedimentation appear to have prevailed on the eastern side of the Atlantic Basin, in Wales, Norway, and Sweden. The great conformable sections of Cambrian strata, in the Rocky Mountain area (Figs. 45, p. 549; 46 and 47, p. 550), do not, as far as known, present evidence of interruption in the sedimentation between the Lower, Middle, and Upper Cambrian strata, except near the eastern shore-line, as in the Wasatch section of Utah (Fig. 46), where strata of Upper Cambrian age do not appear to have been deposited. In Russia, Spain, Sardinia, and on the western side of the Atlantic, in New Brunswick[1] and Massachusetts, the stratigraphic relations of the faunas are not exhibited; and, in the St. Lawrence and Champlain-Hudson areas of America, the data are wanting by which to identify the subfaunas of the Cambrian in any continuous stratigraphic section. As far as known to me, the stratigraphic or physical relations of the faunas, do not furnish sufficient evidence to account for the change from the Olenellus to the Middle Cambrian fauna; and there is no recognized unconformity indicative of a physical and consequent time interruption in the deposition of the sediments that compose the strata containing the Lower and Middle Cambrian faunas.

In the following table the order of succession of the Cambrian faunas is shown, in six typical areas in America:

	Cambrian group.		
	Upper Cambrian.	Middle Cambrian.	Lower Cambrian.
Newfoundland	Olenus zone.	Paradoxides zone.	Olenellus zone.
Massachusetts	Unknown.	Paradoxides zone.	Olenellus zone.
New York	Dicellocephalus zone.	Indicated by other genera than Paradoxides.	Olenellus zone.
Tennessee	Present in part.	Same as in Nevada and Utah.	Olenellus zone.
Nevada and Utah	Dicellocephalus zone.	Represented by other genera than Paradoxides.	Olenellus zone.
Upper Mississippi Valley.	Dicellocephalus zone.	Unknown.	Unknown.

The correlations in the table follow the Newfoundland section. In New York the Paradoxides zone has not been recognized, unless we

[1] Mr. Matthew's later observations indicate that in New Brunswick the representatives of the two faunas occur in several sections.

consider the representative species, *Linnarssonia sagittalis* var. *taconica, Agnostus desideratus*, Agnostus, of the type of *A. pisiformis, Microdiscus connexus* and *Zacanthoides eatoni*, as representing it. This I am at present inclined to do. In Newfoundland the genus Olenus is represented, but in New York, Nevada, Wisconsin, etc., the genus Dicellocephalus is taken as the representative genus of the Upper Cambrian. In the southern Appalachian area, Tennessee, Alabama, etc., the Upper Cambrian fauna is well developed, and the Middle Cambrian fauna is indicated by *Olenoides curticei* n. sp., *Ptychoparia antiquata*, Salter, Agnostus, 2. sp., etc. The Lower Cambrian fauna has been recently discovered and contains Hyolithes, like *H. americanus, Isoxys chilhoweana, Olenellus, sp.?*

The succession of the Cambrian faunas in Europe is, as shown in the following table, essentially the same as on the Atlantic coast of North America.

Table showing the order of succession of the Cambrian faunas in Europe, where the Olenellus zone has been recognized.[1]

[The local sections are given in Dr. Lapworth's paper.]

	Cambrian system.		
	Upper Cambrian or Olenus zones.	Middle Cambrian or Paradoxides zones.	Lower Cambrian or Olenellus zones.
Scandinavia	Dictyonema and Olenus zones.	Paradoxides zones.	Olenellus.
Russia	Dictyonema.	Unknown.	Olenellus.
Britain	Dictyonema and Olenus zones.	Paradoxides zones.	Olenellus.
Sardinia	....	....	Types of the Olenellus fauna, but not Olenellus.

ZOOLOGICAL RELATIONS.

Under this head will be mentioned (1) the species that range from the Lower Cambrian into the Middle Cambrian, in each typical province of the Olenellus fauna; (2) the relation of the genera and species, irrespective of geographic distribution and vertical range; (3) the comparison of the faunas as a whole.

New York and Vermont.—The Olenellus fauna has a great vertical range in Washington and Rensselaer counties, N. Y. I have called it 14,000 feet,[2] but this may be modified by a more detailed study of the sections. About 2,000 feet below the summit of the strata assigned to the Cambrian, the fauna contains *Olenellus asaphoides*, but with it occur the species *Lingulella granvillensis*,

[1] Nature, vol. 39, 1888, p. 213.
[2] Am. Jour Sci., 3d ser., vol. 35, 1888, p. 242.

Linnarssonia sagittalis var. *taconica*, *Agnostus desideratus*, *Agnostus*, of the type of *A. pisiformis*, *Microdiscus connexus*, and *Zacanthoides eatoni*, all of which are representative although not identical species of the Paradoxides fauna of the Atlantic province.

Farther south, in the valley of the Hudson in Dutchess County, Prof. William B. Dwight discovered strata that he considers to be above the quartzite, carrying Olenellus. In it he found several species that may be referred to the Middle Cambrian fauna. They are: *Olenoides stissingensis*, *Leperditia ebinina*, and *Kutorgina stissingensis*. None of these species occurs in the Olenellus fauna, and the Olenoides belongs to the type of the genus occurring in the Middle Cambrian rocks of the Rocky Mountain province. *Kutorgina stissingensis* is the representative of *Kutorgina labradorica*, and *Leperditia ebinina* belongs to a division of that genus that includes an almost identical species from a stratum of rock, referred to the Middle Cambrian, in the Tonto sandstone of the Grand Cañon section of Northern Arizona.[1] As far as these few species can, they indicate that the Middle Cambrian fauna of eastern New York has the same general facies as that of the southern Appalachian region in the State of Georgia and in the Rocky Mountain province.

In the Georgia section of northern Vermont the Olenellus zone has a thickness of about 1200 feet.[2] With the possible exception of *Ptychoparia adamsi* none of the species are known to range upward in the section.

Rocky Mountain province.—In the Rocky Mountain province, the Eureka district and Highland Range sections[3] show the relations of the Lower, Middle, and Upper Cambrian faunas. In each section the Olenellus fauna is confined to a comparatively narrow zone,

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[1]The Tonto section at the head of Nun-ko-weap valley is as follows, from top downward:

	Feet.
1. Massive mottled limestone	60
Fossils: Lingulepis and Ptychoparia.	
2. Evenly bedded yellowish sandstone	25
3. Mottled and variegated calcareo-arenaceous rocks	340
4. Thin-bedded sandstones	325
Fossils, near base: Lingulella, Acrothele, Iphidea ornatella, Hyolithes, Leperditia (3 species), Dilichometopus, Olenoides, and Ptychoparia.	
5. Fine grained, passing into coarse, reddish-brown sandstone in layers.	300
	1,050

The base rests unconformably upon the Chuar shales, etc. Nos. 4 and 5 are referred to the Middle Cambrian, and the strata above to the Upper Cambrian. In the Texas Cambrian section the *Ptychoparia minor* fauna is known from the upper portion of the basal sandstone (see fig. 49, p. 552), and it is not improbable that the Middle Cambrian fauna will be found in the lower portion of the sandstone series.

[2]Bull. U. S. Geol. Survey, No. 30, 1886, pp. 15–20; also p. 552, note 3.

[3]Bull. U. S. Geol. Survey, No. 30, 1886. Introduction.

just above the non-fossiliferous quartzite. In the Eureka district the fauna consists of only six species: *Kutorgina prospectensis, Scenella conula, Olenoides quadriceps, Olenellus gilberti, O. iddingsi* and *Anomocare parvum.* Of these, two species, *Olenoides quadriceps* and *Scenella conula* are found 500 feet higher in the section.[1] The Olenellus fauna, in the Highland Range section, includes only *Cruziana sp. ?, Olenellus gilberti* and *O. iddingsi.*[2] One hundred feet higher in the section *Hyolithes billingsi* is found, and in the Eureka section *Stenotheca elongata* occurs 2,000 feet above the Olenellus zone, although a Lower Cambrian species in the Atlantic province. In the Pioche section[3] the fauna of the Olenellus zone is larger. It includes *Eocystites sp. ?, Lingulella ella, Kutorgina pannula, Acrothele subsidua, Acrotreta gemma, Orthis highlandensis, Olenellus gilberti, Zacanthoides levis, Crepicephalus augusta,* and *C. liliana.* Of these *Eocystites sp. ?* is very doubtfully identified by single plates; *Kutorgina pannula, Acrothele subsidua, Acrotreta gemma,* and *Hyolithes billingsi* pass to the zone above that carrying Olenellus.

In the Wasatch section of Utah *Olenellus gilberti* occurs in a narrow band of arenaceous shale that is subjacent to silico-argillaceous shales, containing a number of species that I formerly referred to the Olenellus fauna. Restricting the fauna to only those species occurring in association with Olenellus or a grouping of species characteristic of the Olenellus zone, where Olenellus is present, all the species, with the exception of *Olenellus gilberti* and *Cruziana sp. ?*, are referred to the Middle Cambrian fauna.

In the section of Mount Stephen and Castle Mountain, in British Columbia, Mr. McConnell[4] found the Olenellus fauna at the base of the Castle Mountain limestone; beneath it there are dark colored argillites and sandstones, estimated at over 10,000 feet in thickness, which correspond in position and character to the pre-Olenellus strata of the Wasatch section, which are referred to the Algonkian period. In the collection made by Mr. McConnell from the Olenellus zone there are *Olenellus* sp. ?, *Ptychoparia adamsi* and *Protypus senectus.* The fauna of the Middle Cambrian zone is 2,000 feet higher up in the section, and includes, in the collection made by Dr. C. Rominger, Sponge ?, *Lingulella macconnelli* Walcott, *Crania ? columbiana* Walcott, *Linnarssonia,* like *L. sagitallis* Salter, *Acrotreta gemma* var. *depressa* Walcott, *Kutorgina pannula* White, *Kutorgina,* like *K. whitfieldi, Orthis ?* sp., *Orthisina alberta* Walcott, *Scenella conula ?* Walcott, *Platyceras romingeri* Walcott, *Hyolithellus,* like *H. micans* Billings, *Agnostus interstrictus* White, *Karlia stephenensis*

[1] Op. cit., p. 32. [2] Op. cit., pp. 33, 34. [3] Op. cit., p. 35.

[4] Geol. and Nat. Hist. Survey Canada, Ann. Rept., new ser., vol. 2, 1887; Rept. Geol. Structure of a portion of the Rocky Mountains, p. 29 D.

Walcott, *Olenoides nevadensis* Meek, *Zacanthoides spinosus* Walcott, *Bathyuriscus howelli* Walcott, *B.* (*Kootenia*) *dawsoni* Walcott, *Ogygopsis klotzi* Rominger (sp.), *Ptychoparia cordilleræ* Rominger (sp.).

As known at present six species only pass from the Olenellus zone to the superjacent strata, in the Rocky Mountain province. They are: *Kutorgina pannula*, *Acrothele subsidua*, *Acrotreta gemma*, *Scenella conula*, *Hyolithes billingsi*, and *Olenoides quadriceps*. Of these *Acrotreta gemma* extends up to the Upper Cambrian zone, in Montana.

Newfoundland.—The fauna of the Olenellus zone contains but one species that ranges up into the Paradoxides zone—*Hyolithes princeps*. *Agraulos strenuus* is closely allied to *Agraulos socialis* of the Paradoxides fauna, and *Platyceras primævum* is very like *P. minutissimum* of the Upper Cambrian.

The review of the sections shows but little specific relationship between the two faunas, as only nine species are now known to range from zone to zone. A review of the genera shows a large percentage common to the two zones. Of the sixty-eight genera of the Olenellus zone forty-seven pass up into the Middle Cambrian.

The genera confined to the Lower Cambrian, in America, are:

Leptomitus.	Hyolithellus.
Protopharetra.	Isoxys.
Spirocyathus.	Protocaris.
Coscinocyathus.	Olenellus.
Ethmophyllum.	Bathynotus.
Modioloides.	Avalonia.
Fordilla.	Oryctocephalus.
Helenia.	Protypus.
Coleoloides.	

Of the European genera, the following five are referred only to the Lower Cambrian:

Mickwitzia.	Medusites.
Volborthella.	Fræna.
Platysolenites.	

RELATIONS OF THE GENERA AND SPECIES.

The comparison between the two subfaunas will be made by considering the genera and species of each class of the Lower Cambrian and comparing it with the same class of the Middle Cambrian fauna.

No traces of land vegetation have been discovered in the rocks of the Cambrian Period.

Algæ.—As far as known to me there are no true Algæ in the rocks of the Lower Cambrian. That such forms existed there can scarcely be any doubt, but after a study of all the reported species, I think that they can be referred to trails of worms or mollusks with much more propriety than to the Algæ. Specimens of Cruziana collected in

Newfoundland lead me to think that it is a trail or burrow and not an Alga.[1]

Spongiæ.—The sponges of the Lower Cambrian are limited to four genera, of which one, Protospongia, is found in the upper beds of the Olenellus zone of the Atlantic province, and also in the Middle Cambrian in Nevada, New Brunswick, Newfoundland, Wales, and Sweden. Leptomitus is confined to the Lower Cambrian.

Hydrozoa.—It is to the researches of Dr. A. G. Nathorst that we owe a knowledge of the occurrence of Medusæ in the Lower Cambrian rocks of Sweden. By a series of comparisons between the casts found in the rocks at Lugnas and the casts made by the impressions of recent Medusæ, more especially of *Aurelia aurita* and *Cyrena capilata*, he has shown that it is extremely probable, if not certain, that the delicately constructed Medusæ lived during the Lower Cambrian epoch and left traces of their existence in the clays and sands of the sea-shore. Dr. Nathorst[2] figures and describes *Medusites lindstromi* Linnrs., *M. favosus* Nathorst and *M. radiata* Linnrs., and states that he thinks the species of Eophyton are the casts of trails made by the Medusæ in moving along the sea-bed. The form described as *Dactyloidites asteroides* may be referred provisionally to the Medusæ and thus give an American species from the Lower Cambrian. There are in the collections of the U. S. Geological Survey a group of forms from the middle part of the Cambrian in Alabama, that appear to be generically related to *Medusites lindstromi.* They will be described in an account of the Middle and Upper Cambrian fauna. In ascending the geological scale, it is not until the lithographic slate of the Upper Jura, at Solenhofen, etc., is reached, that traces of the Medusæ are again met with.

The Graptolitidæ is represented by two species that are provisionally referred to the genera Phyllograptus and Climacograptus. These generic types are not met with again until the base of the Silurian is reached, where they are largely developed. Mr. Matthew has described two species of Graptolites from the Middle Cambrian of New Brunswick, which he refers to Dendrograptus and Protograptus.

Actinozoa.—It has been an open question for some years whether the forms referred to the genus Archæocyathus were corals or sponges. Dr. G. J. Hinde has recently reviewed the genera and species, and

[1] Since the preceding was written Mr. Matthew's paper has appeared, in which he describes *Buthotrephis antiqua*, *Phycoidella stichidifera*, *Palæochorda setacea*, *Hydrocytium ? silicula*, and *Microphycus catenatus* as Algæ. He also describes under the Monera Radiolaria ?, *Monadites globulosus*, *M. pyriformis*, *M. urceiformis*, and *Radiolites ovalis*.—(On Cambrian Organisms in Acadia, Trans. Roy. Soc. Canada, vol. 7, sec. iv, 1890, pp. 144–148.)

[2] Kongl. Svenska Vetenskaps-Akademiens Handlingar, Bandet 19, N. 1, 1881. Om Aftryck af Medusor i Sveriges Kambriska Lager.

concluded that they form a special family of the *Zoantharia sclerodermata*, in some features allied to the group of perforated corals. A restudy of all the species and a personal examination of Dr. Hinde's specimens leads me to agree with him that they should be referred to the Actinozoa. With the exception of the single doubtful species of Archæocyathus described by Mr. Matthew, from the Paradoxides zone of St. John, New Brunswick, *A. ? pavonoides*, there are no representatives of this family (Archæocyathinæ) in the later Cambrian. The first true corals met with in the ascending series occur near the base of the Silurian fauna.

Echinodermata.—The Echinodermata are represented by a few scattered plates of a species of Cystid, which is referred provisionally to the genus Eocystites. It is impossible to make any comparison between it and the Cystids of the Middle Cambrian.

Annelida, etc.—The trails, burrows, and tracks of animals that occur in the Lower Cambrian are nearly all duplicated in the Upper Cambrian. This is true of the genera Planolites, Helminthoidichnites, Scolithus, and Cruziana, of the American rocks. As far as determined by traces left by their passage the same type of animals existed throughout Cambrian time.

Brachiopoda.—The Brachiopoda, with 10 genera and 29 species, affords a much broader opportunity for comparison, but even here the specific connection is very slight between the two zones. Of the genera, Lingulella is represented in the Paradoxides zone by a group of forms that have received the names *L. linguloides and L. dawsoni* in New Brunswick; *Lingulella sp.*, in Linnarsson's Brachiopoda of the Paradoxides beds of Sweden (Plate 3, Figs. 24–28), and *L. granvillensis* in the Olenellus zone of New York. The species of the genus Acrotreta. of the Paradoxides zone of Sweden and New Brunswick, and the Middle Cambrian zone of the Rocky Mountain province, are so closely allied to the species from the Olenellus zone in Nevada that we consider that one species, *A. gemma*, ranges from the base of the Cambrian through to the Upper Cambrian. *Acrothele subsidua* also ranges from the Lower Cambrian to the Middle Cambrian, in the Rocky Mountains; and *A. matthewi*, of the Paradoxides zone of New Brunswick, is a closely allied if not identical species. The genus Iphidea has a vertical range from the Olenellus zone in Labrador to the Middle Cambrian in Sweden, where it is found in the Paradoxides beds. A very closely allied species also occurs in the lower portion of the Cambrian section in the Grand Cañon of the Colorado of Arizona, a horizon that will probably be referred to the Middle Cambrian. The genus Kutorgina has one species, *K. labradorica*, that has a wide geographic range, and a closely allied, representative species, *K. stissingensis*, occurs in the Middle Cambrian zone of New York. *K. pannula* ranges from the Olenellus zone to the Middle Cam-

brian in Nevada, and is found in the upper portion of the Olenellus zone in New York.

Linnarssonia sagittalis var. *taconica* is scarcely to be considered a typical Olenellus zone species, as it occurs so high in the Lower Cambrian section. Still, as it is associated with Olenellus we may consider it as forming a part of the fauna, and compare it directly with the same species as found in the Paradoxides zone of New Brunswick and Sweden. Of the six species of the genus Obolella none are known to occur in the Middle Cambrian, and it is not until we reach the Upper Cambrian that we find representatives of the genus. The genus Orthis, as represented by *O. salemensis* and *O. highlandensis* (the broad and narrow hinge types), is not known to occur in the Middle Cambrian zone, although both forms of the genus are represented in the Silurian. Among the species referred to Orthisina, we find that *O. orientalis* is very closely related to *O. pepina*, of the Upper Cambrian; also that *O. festinata* is of the type of *O. exporecta* of the Paradoxides zone of Sweden, and *Orthis billingsi* of the New Brunswick Middle Cambrian. *Camerella antiquata* and *C. minor* have no known representatives in the Middle or Upper Cambrian.

As a whole, the Brachiopoda are strongly represented in the Lower Cambrian and do not exhibit any special evidence of embryonic character when compared with the fauna of the Middle and Upper Cambrian. If, however, the comparison is extended to the Upper and Lower Silurian faunas, etc., the predominance of the inarticulate shells of the families Obolellidæ, Siphonotretidæ, and Lingulidæ over the articulate shells of the Orthidæ and Rhynchonellidæ, in the Cambrian indicates that the general law of progressive evolution in this class finds expression in the small number of articulate brachiopods in the Cambrian as compared with the later faunas and the predominance of the inferior inarticulate species.

Lamellibranchiata.—The genus Fordilla and the form described as *Modioloides prisca* appear to be the representatives of the Lamellibranchiata in the Olenellus zone. The presence of these two shells is of unusual interest, as none of the same class are met with in the geologic succession before the abrupt appearance of the group of species in the Arenig (Lower Silurian) strata of South Wales.

Gasteropoda.—Among the Gasteropoda, the genus Scenella is represented in the Upper Cambrian by simple Patelloid shells. It has not been found in the Paradoxides fauna of the Atlantic Basin, but in the Middle Cambrian strata of the Mt. Stephen section in the Rocky Mountains a representative species was found by Dr. Rominger. The forms referred to the genus Stenotheca are very closely allied if not identical in the Lower and Middle Cambrian zones. *S. rugosa*, of the Lower Cambrian, and *S. acadica* of the Paradoxides zone are examples of this intimate specific relationship. The little

Platyceras of the Lower Cambrian has a representative, *P. romingeri*, in the form described from the Mt. Stephen Middle Cambrian fauna of British Columbia. A single species in the Upper Cambrian connects this genus with the Ordovician fauna. *Pleurotomaria attleboroughensis* does not appear to have a representative before reaching the Lower Ordovician fauna, and *Straparollina remota* has no connection through the known Middle Cambrian fauna with the fauna of the Lower Silurian.

Pteropoda.—The four genera and fifteen species of this class are very strongly related to those of the Middle Cambrian fauna. *Hyolithes princeps* is a large form that is very abundant in the Olenellus zone, and it has a great geographic range. It is found in western Nevada, eastern Massachusetts, and eastern Newfoundland. A closely allied if not identical species occurs in the Paradoxides zone in Newfoundland. *H. maximus* of the Paradoxides zone of Bohemia is of this same specific type, although differing considerably in detail of form. *H. americanus* is very closely related in form to *H. acadica* of the Paradoxides zone in New Brunswick, and the same type is abundant in the Upper Cambrian of the Mississippi Valley, under the name of *H. primordialis*. *H. billingsi* is known to range from the Lower to the Middle Cambrian, and has been found in Labrador, New York, and Nevada. *H. communis*, *H. impar*, *H. quadricostatus*, and *H. terranovicus* are species which do not appear to have representatives in the Middle Cambrian fauna. *H. similis* is very much like *H. primus* of the Paradoxides zone of Bohemia. The genera Hyolithellus and Coleoloides do not appear to be represented by well authenticated species in the Middle Cambrian. Salterella is not met with again until the Ordovician fauna is reached and there very doubtfully.

Crustacea.—Of the true crustaceans, *Leperditia dermatoides* has a close specific relationship with an undescribed species from the Middle Cambrian of the Grand Cañon section of Arizona; and a representative species, *L. stissingensis*, occurs in the New York Middle Cambrian. The newly described type *Isoxys chilhoweana* is, as far as known to me, distinct from more recent genera.

The genus Aristozoe, although abundantly represented in the Silurian fauna of Europe, is not known from the Middle Cambrian. *Protocaris marshi* still remains the oldest known Phyllopod crustacean. The Upper Cambrian Phyllopod, *Hymenocaris vermicauda*, is the next met with, unless some of the forms referred to Stenotheca, in the Paradoxides zone, are portions of the carapace of some species whose generic relations are undetermined.

Trilobita.—The sixteen genera and fifty-three species of trilobites constitute less than one-third of the entire fauna. The range of variation among the genera and species includes forms with and without eyes, and with and without facial sutures. One of the sur-

prising facts is that the genus Agnostus, which has been theoretically considered the ancestral form of the trilobite, does not appear to exist in the lower portion of the Olenellus fauna, but, as shown by Brögger, in Sweden it is more typical of the Middle Cambrian than of the Olenellus zone. The undoubted species of the genus known from the Olenellus zone are found in the upper portion, in association with types of the Middle Cambrian fauna. The reference of *Agnostus nobilis* Ford, from the lower part, to Agnostus is very doubtful, as the form is probably a Microdiscus. The type which, by a priori reasoning, should succeed Agnostus is Microdiscus, with its three and four segments and eyeless cephalic shield. As known, however, it occurs at the base of the Olenellus zone, and its specific variations indicate prolonged existence in a period of which the record has not yet been discovered. Reaching its known maximum development, in species and size, in the Olenellus zone, the genus diminishes in the Paradoxides zone in about the same ratio that Agnostus increases in importance. In the Upper Cambrian Microdiscus is represented only by *Pemphigaspis bullata* Hall. Agnostus continues on into the Ordovician fauna. *Microdiscus connexus*, of the upper portion of the Olenellus zone, in New York, is the Paradoxides zone type of the genus, i. e., *M. punctatus*, while *M. sculptus*, of the Lower Paradoxides zone of South Wales, is the Olenellus zone type, i. e., *M. speciosus*.

The genus Olenellus has been found wherever the Lower Cambrian fauna is known, except in New Brunswick. It presents great variation in specific characters, and I have included several of the species in the subgenus Mesonacis, and Mr. Matthew has proposed the genus Holmia to include *O. kjerulfi*. The marked difference between this genus and Paradoxides is the absence of true facial sutures and in the general configuration of the central portion of the head, more notably in the form of the eye. Among the species of Paradoxides the eyes of *P. rugulosus* Corda and the group of species from the St. John terrane, of New Brunswick, approach most nearly to those of Olenellus. In the type, *O. thompsoni*, the distinction between it and Paradoxides is very striking. The absence of facial sutures and the long spine-like telson finds no counterpart in the latter. *O.* (*Mesonacis*) *vermontana* has the typical Paradoxides form of pygidium; also a peculiar posterior series of thoracic segments that are related to those of Paradoxides. This species appears as a link between the type *O. thompsoni* and the remaining species referred to the genus, all of which have a pygidium like that of Paradoxides, and none of the pleuræ of the thoracic segments are prolonged, as in the type of the genus and in the young of some species of Paradoxides.

I call attention here to the fact that while no true facial sutures exist in Olenellus, there is, on the underside of the test of the

head, a line-like depression that corresponds in position to the suture in Paradoxides. It may be well to note that Olènellus resembles the living Limulus in having well developed eyes, without the presence of facial sutures. The external resemblance to Limulus is further enhanced by the telson-like pygidium of *O. thompsoni*. The structure of the cephalic appendages of the trilobite also relate it to Limulus.[1] If we consider the head of Limulus as belonging to a more highly organized form than the head of Paradoxides, the fact that the head of Olenellus is without facial sutures does not make it rank below Paradoxides. In fact *Olenellus* (H.) *bröggeri*, of Newfoundland, impresses me as being as highly, if not more highly, organized than any of the species of Paradoxides. *Olenellus thompsoni* and *O. gilberti* might be considered the progenitors of Paradoxides, inasmuch as they have a strong development of the pleura of one of the thoracic segments, a feature that is present in the young of *P. bohemicus*, but does not continue to the adult.

American paleontologists have considered the genus Olenellus as the descendent of Paradoxides, but the fact of occurrence proves such a theory to be incorrect. The argument advanced by Mr. Ford[2] that the young of *Olenellus asaphoides* passed through the Paradoxides stage, in its embryonic development, may be explained in another way, by assuming that the species of Olenellus, having the pleuræ of the third segment prolonged (macropleural) originated earlier than those with the pleuræ of uniform length (brachypleural), and hence the prolonged pleuræ are shown only in the embryonic phases of growth in the brachypleural species. As pointed out by Ford, the genus Paradoxides, like Olenellus, has brachypleural and macropleural species, but it is significant that it is in the young of Paradoxides that the macropleural features of *O. thompsoni* are developed, while in the adult it is reduced to a very insignificant character. That a genetic relationship exists between Olenellus and Paradoxides there is considerable probability. Olenellus exhibits greater specific variation and is more diversified by spines on the head and thorax, but in the essential elements of structure it is related to Paradoxides, except in the absence of true facial sutures. Just what weight to give this character is not fully decided, although I am inclined to refer the two genera to distinct families. With the exception of *O.* (*Mesonacis*) *vermontana*, there are no known connecting species between the typical forms of the two genera.

The genus Olenoides is largely developed in the Middle Cambrian of the interior of the continent. One species only, *O. marcoui*, is found in the lower portion of the Olenellus zone. Two other species, *O. fordi* and *O. quadriceps*, are in the upper portion, near the passage between the Lower and Middle Cambrian. As far as the

[1] Bull. Mus. Comp. Zool., Harvard College, vol. 8, No. 10, 1881, pp. 208–211.
[2] Am. Jour. Sci., 3d ser., vol. 22, 1881. pp. 250–259.

specimens of *O. marcoui* of the Lower Cambrian will permit of comparison it is closely related to *O. nevadensis* of the Middle Cambrian. The two species of Zacanthoides, *Z. eatoni* and *Z. levis*, are representative species of the genus, and serve to unite the fauna with that of the Middle Cambrian, as *Z. typicalis* and several species occur in the Middle Cambrian of the interior of the continent. The genera Bathynotus, Avalonia, Oryctocephalus, and Protypus are peculiar to the fauna, and do not appear to be represented in the Middle or Upper Cambrian faunas.

Conocoryphe trilineata and *C. reticulata* are two of the best marked types in the New York Lower Cambrian; they are closely related to *C. elegans* and *C. coronata*, of the Paradoxides zone, in having the same general form and in the absence of eyes. The genus Ptychoparia is represented by nine species, all of which are more or less closely related to forms in the Middle and Upper Cambrian. *Agraulos strenuus* is represented in the Upper Cambrian by *A. socialis*. *Ellipsocephalus nordenskioldi*, of Sweden, is represented by *E. hoffi* of the Paradoxides zone of Bohemia. *Crepicephalus augusta* and *C. liliana* are types that are more or less abundant in the Upper Cambrian fauna of the interior of the continent. They are not represented, to my knowledge, in the Middle Cambrian fauna. The small head that I have referred to *Anomocare parvum* may be compared to *A. limbatum* of the Paradoxides beds of Sweden. The genus Solenopleura, with its five species, is also well developed in the Middle Cambrian fauna. *S. howleyi*, from the base of the Olenellus zone of Newfoundland, is very closely related to the type of the genus *S. holometopa* of the Paradoxides zone of Sweden.

COMPARISON OF THE FAUNAS AS A WHOLE.

The first thing that strikes one in comparing the fauna of the Olenellus zone with that of the Middle Cambrian is that the latter is not wholly known, or, in other words, there existed somewhere a Middle Cambrian fauna, which has not yet been discovered. We are now obtaining evidence of a considerable fauna that existed during Middle Cambrian time on the western slope of the Appalachian shore, and on the west coast of what then existed as the North American Continent. Of this fauna there is scarcely any representation known in the Middle Cambrian or Paradoxides fauna of the Atlantic province. This adds to the fauna, but there is still a notable absence of certain forms in the Middle Cambrian fauna which are present in the Lower Cambrian. The first noticeable exception is the absence of representatives of the peculiar group of corals that occur in the Olenellus zone. With a single possible exception, the Archæocyathinæ are not represented in the Middle Cambrian. Among the Brachiopoda the genus Obolella has a large development in the Lower Cambrian and is present in the Upper Cambrian, but

is scarcely represented in the Middle Cambrian; and the Brachiopoda, as a whole, are more largely developed in species and number of individuals than in the Middle Cambrian. Lamellibranchs are represented in the Lower Cambrian, but not in the Middle Cambrian. Among the Gasteropods, Pleurotomaria and Straparollina are yet to be discovered in the Middle Cambrian. The same is true of the Phyllopod crustacean *Protocaris marshi*.

Viewing the Olenellus fauna as a whole and comparing it with the known Middle Cambrian fauna of the Atlantic basin, or the Paradoxides fauna, the impression made is that the former is more highly differentiated, and, zoologically considered, should be the successor of the Paradoxides fauna. If, in our comparison, we include the Middle Cambrian fauna of the interior of the continent, this conclusion will be changed, owing to the presence of a group of trilobites, from the Middle Cambrian of Nevada, Utah, and British Columbia, that includes the genera Olenoides, Asaphiscus, Bathyuriscus, Karlia, and Ogygopsis. These genera suggest the trilobites of the second or Ordovician fauna, and serve to connect the Middle Cambrian fauna so closely with the second fauna that the idea of its preceding the Olenellus fauna can not be entertained.

It was owing to the comparison made between the two faunas in the Atlantic basin that led me to so long retain the view that the Olenellus fauna succeeded the Paradoxides fauna in time, and to think that the Paradoxides fauna would be found, if at all, beneath the Olenellus zone, in the interior of the continent. Now that we know that the Olenellus fauna occurs beneath the Paradoxides zone in America, and that there is a representative Middle Cambrian fauna in the Valley of the Hudson, that serves in a measure to connect the Paradoxides fauna of the Atlantic basin and the Middle Cambrian fauna of the interior of the continent, there is no hesitation in referring the group of species, forming the fauna between the Olenellus and the Upper Cambrian zone, in the Appalachian and Rocky Mountain provinces, to the Middle Cambrian, and in correlating its stratigraphic position with that of the Paradoxides fauna of the Atlantic province.

The cause of the abrupt change from the Olenellus to the Paradoxides faunas is not yet fully recognized. While a considerable portion of the genera pass up, very few of the species are known to do so, and in none of the sections has there been found a commingling of the characteristic species of the Lower and Middle faunas. I shall advert to this question again, in preparing the review of the Middle Cambrian fauna which is now in hand.

ORIGIN OF FAUNA.

If we attempt to classify the Olenellus fauna by its genesis, an almost impenetrable wall confronts us. That the life in the pre-

Olenellus seas was large and varied there can be little, if any, doubt. The few traces known of it prove little of its character,[1] but they prove that life existed in a period far preceding Lower Cambrian time, and they foster the hope that it is only a question of search and favorable conditions to discover it. As far as known to me, the most promising area in which to search for the pre-Olenellus fauna is on the western side of the Rocky Mountains in the United States and on their eastern slopes in British Columbia. There the great thickness of conformable pre-Olenellus zone strata presents a most tempting field for the student collector. Another of the known possible areas is that of New York and Vermont, but the prospect is not as favorable as in the West. Other and better fields may exist in Asia and Africa, but as yet they are unknown, with the exception of the areas described by Baron Richthofen in China,[2] where a great thickness of conformable sedimentary beds exists beneath a horizon that is comparable with the Middle Cambrian of western North America.

COMPARISON AND CORRELATION.

If a comparison is made between the fauna of the Olenellus zone and that of the Silurian group the superiority of the latter in number of species, genera, and families is at once apparent. If the comparison is extended to class characters the disparity between the two is very much reduced and it is made evident that the evolution of life between the epoch of the Olenellus fauna and the epoch of the Ordovician fauna has been in the direction of differentiating the class types that existed in the earlier fauna, with one or two exceptions, the most notable of which is the Cephalopoda. The classes represented by non-testaceous species may or may not have existed. The study of the Olenellus fauna adds a little more to our knowledge of the rate of convergence backward in geologic time of the lines representing the evolution of animal life, and at the same time proves that an immense time interval elapsed between the beginnings of life and the epoch represented by the Olenellus fauna.

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[1] See ante, p. 552. In 1874, (Palæozoic Fossils, vol. 2, part 1, 1874, pp. 76, 77), Mr. Billings described some fossils from the "Huronian rocks" of Newfoundland. They were *Aspidella terranovica*, a fossil resembling in some respects a small Chiton, or Patella flattened by pressure, but whose true zoological relations are unknown. Associated with it are numerous specimens of what appear to be *Arenicolites spiralis*. As far as known these are the only fossils found in the Algonkian rocks beneath the Cambrian of Newfoundland.

From the red quartzite at Pipestone, Minnesota, Prof. N. H. Winchell describes *Lingula calumet* and *Paradoxides barberi*. The latter, I think, was founded on a concretion, but the *Lingula calumet* has in many respects a strong resemblance to a crushed form of Obolella. It may be for the present considered as one of the doubtful fossils of the Algonkian rocks. Geol. Nat. Hist. Survey of Minnesota, 13th Ann. Rep., 1885, pp. 65–68.

[2] China. vol. 2, pp. 94, 100, 101.

Correlation.—It is not desirable in this place to enter into a discussion of the principles or criteria of correlation employed in this paper except very briefly. In the broadest sense three principles are made use of:

1. Superposition, or stratigraphic position of the strata.
2. The occurrence of similar groupings of organic remains.
3. The occurrence of similar lithologic characters.

In correlating the Lower Cambrian strata of one geologic province with what are considered to be equivalent strata in other provinces, the order of superposition is considered where the relations to the subjacent and superjacent rocks are known.

The presence of the Olenellus fauna is, however, regarded as the strongest test and it is chiefly used in determining the presence of the Lower Cambrian zone in any geologic section. It is assumed that the presence of this fauna indicates the same relative geologic horizon. It is not implied that the formations characterized by the Olenellus fauna are strictly contemporaneous wherever found. On the contrary, its presence in such widely separated localities as England, Newfoundland, Tennessee, Nevada, and British Columbia, is *prima facie* evidence that the deposits are not strictly contemporaneous. This is supported by the known laws of geographic distribution of animal life. That they were contemporaneous in a geologic sense, or that they occupy the same relative position in the geologic sequence of formations, is accepted throughout this paper.

The use of lithologic characters is of much less importance than either stratigraphic position or similarity of organic remains, and is used only within a district, area, or province.

If the reader wishes an analysis of the elements of correlation used in each instance it may be obtained by comparing the data given in each separate area, district, or province, with that of the area, district, or province with which it is correlated either directly or by implication. He will thus determine the amount and character of the evidence upon which the correlations between the several districts, areas, or provinces have been based.

As an element of weakness in paleontologic correlation, we may cite the character of the Middle Cambrian or Paradoxides fauna of the Atlantic province as compared with the essentially different Middle Cambrian fauna of the Rocky Mountain province. The position of the latter in the geologic series would not be inferred from its zoologic characters. It is only its occurrence at a horizon between the Lower and Upper Cambrian faunas that gives any strong reason for correlating it with the Paradoxides fauna. The latter retains all the essential characters of the Primordial fauna, whereas the former partakes in its trilobites largely of the characters that are more typical of the Ordovician fauna. It appears from what we now know of the two, that the Middle Cambrian fauna of the Rocky

Mountain province had advanced further in development toward the Ordovician fauna than had the Paradoxides fauna of the Atlantic province. It is an interesting fact in this connection that the Upper Cambrian fauna of the Rocky Mountain province and the Atlantic province appears to be essentially of the same grade or phase of development. What became of the descendants of the Middle Cambrian fauna of the Rocky Mountain province during Upper Cambrian time is one of the unsolved problems.

X. NOTES ON THE GENERA AND SPECIES.

Many of the genera and species have already been described at length in Bulletin 30 of the U. S. Geological Survey, and the student is referred by the citation given under such genera and species to the place of description. In the case of new genera and species, original observations on described genera and species, or descriptions that have not appeared in publications of the Geological Survey, most of the descriptions are published at length.

Following each species a reference is given to the location of the type specimens, or, if the specimens are in the collections of the U. S. National Museum a reference is made to the number under which they are entered in the Museum catalogue.

SPONGIÆ.

Genus LEPTOMITUS Walcott, 1886.

Bull. U. S. Geol. Survey, No. 30, p. 89.

LEPTOMITUS ZITTELI Walcott, 1886.

(Pl. XLIX, figs. 1, 1*a*.)

Bull. U. S. Geol. Survey, No. 30, p. 89.

A sponge related to the glass-rope sponge, Hyalonema.

Nat. Mus. Cat. Invert. Foss., 15308.

Genus PROTOSPONGIA Salter.

Bull. U. S. Geol. Survey, No. 30, p. 90.

PROTOSPONGIA sp. ?.

(Pl. XLIX, fig. 2.)

Numerous spiculæ, similar to those of *P. fenestrata* Salter, occur in the upper portion of the Olenellus zone in Washington County, N. Y. As far as can be determined they are identical with the Middle Cambrian form, which is figured in Bulletin 30, U. S. Geological Survey. Pl. VI, Figs. 2, 2*a*–*b*.

Nat. Mus. Cat. Invert. Foss., 17438.

GIRVANELLA Nich. and Eth., jun.

Mon. Sil. Foss., Girvan Dist. 1, 1878, p. 23. Mentioned as Strephochetus, Seely. See Bull. U. S. Geol. Survey, 1886, p. 91.

(Pl. LX, fig. 4.)

That the forms found at Prospect and Silver Peaks, Nevada, are generically identical with Girvanella is extremely uncertain. Nothing is known of the minute structure. They are apparently organic and resemble *Girvanella ocellatus* Seely in external appearance. Whether the form is a Sponge or a Rhizopod is also uncertain.

Nat. Mus. Cat. Invert. Foss., 15311.

TRACHYUM Billings, 1865.

Trachyum vetustum Dawson.

Trachyum vetustum Dawson, 1890. Received in MSS. from Sir William Dawson, accompanied by figure and description.

Small rounded and irregular bodies, 6^{mm} and less in diameter, calcareous, and imbedded in a finely granular limestone, partly oolitic and with rounded siliceous grains. Occurring in groups on the weathered surface as if possibly attached to each other below.

The best specimens show on the weathered surface a circular outline, with a thick wall and central canal, cup, or osculum, usually small in comparison with the thickness of the wall. The weathered surface appears finely granular, with obscure, radiating grooves and ridges.

A transparent slice shows a badly preserved reticulated structure, which may in a general way be compared with that of Protopharetra from the Cambrian of Sardinia, or with the basal portion of some species of Archæocyathus, though of finer texture. The pores traversing this structure would seem, though irregular, to have been on the whole arranged in an obliquely radiating manner, and to have terminated in rows of openings at least on the inner surface. The structure, however, is very imperfect and masked by a general finely granular crystallization.

The specimens occur in the bowlders in the Quebec group conglomerate of Metis, along with the Lower Cambrian trilobite (*Ptychoparia metisensis*), described by Mr. C. D. Walcott, and are therefore of the same age; and if sponges, among the oldest known, and probably referable to the calcareous group of Pharetrones of Zittel. In texture these fossils bear a close resemblance to the genus Trachyum of Billings, represented by two species from the Quebec group of Cape Norman, Newfoundland.[1]

[1] Palæozoic Fossils, vol. 1, p. 211.

The weathered specimens are, indeed, except by their smaller size and less open cup or osculum and different state of preservation, scarcely distinguishable from one of Billings's species. For this reason they may, for the present, be referred to the above genus.

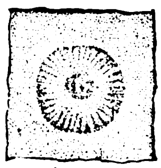

FIG. 60.—*Trachyum vetustum*. Weathered cross-section. x2.

A slice of one of the specimens shows imbedded in the wall what seems to be a section of a microscopic spiral shell without septa.

ACTINOZOA.

For a number of years it has been an open question whether the forms included under the genus Archæocyathus of Billings were allied to the corals or sponges. The first reference to them is by Captain Bayfield,[1] who mentioned finding a Cyathophyllum in Labrador, in 1845. Since Mr. Billings's paper in 1861 authors have varied in their opinions.[2] Quite recently Dr. G. J. Hinde has reviewed the genera and species, and concludes that "the Archæocyathinæ form a special family of the Zoantharia sclerodermata, in some features allied to the group of perforate corals."

Although previously inclined to consider the forms under notice sponges, I am now of the opinion that Dr. Hinde is more nearly correct in referring them to the corals.

PROTOPHARETRA Bornemann.

Geol. Zeitschr., 1883, p. 274.

PROTOPHARETRA sp.?

(Pl. LI, figs. 1, 1*a*.)

This is a form related to *P. polymorpha* Bornemann.[3] It varies in form of growth from round stems to flattened fronds, in which the structure is very irregular. It is an open question if *Spirocyathus atlanticus* is not generically identical with Protopharetra.

Formation and locality.—Lower Cambrian; Silver Peak, Nevada.

Nat. Mus. Cat. Invert. Foss., 15303.

SPIROCYATHUS Hinde.

Quart. Jour. Geol. Soc. London, 1889, vol. 45, p. 136.

This genus is proposed to include the original type of the genus Archæocyathus. As the change to another type was made by Mr. Billings and no good result can now come from urging the use of

[1] On the junction of the transition and primary rocks of Canada and Labrador; H. W. Bayfield. Quart. Jour. Geol. Soc. London, vol. 1, 1845, pp. 450–459.

[2] See Bull. U. S. Geol. Survey, No. 30, 1886, pp. 78–80.

[3] Nova. Acta. Leop.—Carol. Deutsche Akad. Naturforscher., vol. 51, pt. 1, 1886.

the name Archæocyathus to include the species *S. atlanticus*, it appears best to accept Dr. Hinde's generic name.

SPIROCYATHUS ATLANTICUS, Billings (sp.).

(Pl. L, figs. 1, 1*a–f*. 2, 2*a*.)

See Bull. U. S. Geol. Survey, No. 30, p. 73.

There is quite a variation between the specimens representing this species, as shown by Figs. 1*b*, 1*c*, 1*e*, 2, 2*a*. They are not considered of specific importance.

Formation and locality.—Lower Cambrian; on the Straits of Belle Isle, Labrador, and Silver Peak, Nevada. Longitude 117° 20′ W., latitude 38° N.

Nat. Mus. Cat. Invert. Foss., 15301.

COSCINOCYATHUS Bornemann.

Zeitschr. Deutsch. geol. Gesell., 1884, p. 704.

COSCINOCYATHUS BILLINGSI Walcott.

(Pl. LI, figs. 2, 2*a*, *b*.)

Archæocyathus billingsi Walcott. See Bull. U. S. Geol. Survey, No. 30, p. 74.

By the subdivision of the genus Archæocyathus this species is referred to Coscinocyathus.

Nat. Mus. Cat. Invert. Foss., 15302.

ARCHÆOCYATHUS Billings.

ARCHÆOCYATHUS PROFUNDUS Billings (sp.)

(Pl. LII, figs. 1, 1*a–c*; Pl. LIII, figs. 1, 1*a–b*; Pl. LIV, fig. 3.)

Ethmophyllum profundum Walcott. See Bull. U. S. Geol. Survey, No. 30, p. 84.

The recent studies of Dr. Hinde[1] resulted in his retaining the genus Ethmophyllum and Archæocyathus and proposing the new generic name Spirocyathus for the original type species of Archæocyathus. This appears to be the best way out of the difficulty caused by Mr. Billings defining his genus from one species and citing another as its type.

Formation and locality.—Lower Cambrian; L'Anse au Loup, Straits of Belle Isle, Labrador.

Nat. Mus. Cat. Invert. Foss., 15304.

Subgenus ARCHÆOCYATHELLUS Ford.

ARCHÆOCYATHUS (A.) RENSSELAERICUS Ford.

(Pl. LIV, figs. 1, 1*a–e*.)

Archæocyathus rensselaericus Ford. See Bull. U. S. Geol. Survey, No. 30, p. 85.

This species differs from the typical form of Archæocyathus in having a poriferous outer wall. In this respect it is identical with

[1] Quart. Jour. Geol. Soc. London, vol. 45, 1889, pp. 125–148.

Ethmophyllum, but it does not have the peculiar set of canals attached to the inner wall. It is an intermediate type between the two genera, and may be referred to Archæocyathellus, the latter being considered a subgenus.

Formation and locality.—Lower Cambrian; Conglomerate limestone on the ridge east of the city of Troy, N. Y.

Nat. Mus. Cat. Invert. Foss., 15305.

ARCHÆOCYATHUS (A.) DWIGHTI Walcott.

(Pl. LIV, figs. 4, 4*a*.)

Archæocyathus (*A.*) *dwighti* Walcott, 1889, U.S. Nat. Mus., Proc., vol. 12, p. 34.

This species differs from *A.* (*A.*) *rensselaericus* in having, in the outer wall, a double row of pores and then a raised space upon which no pores have been detected. Interior structure unknown.

Formation and locality.—Lower Cambrian; Troy, N. Y., and near School House No. 8, Greenwich, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 18352.

ARCHÆOCYATHUS (A.) RARUS Ford.

(Pl. LIV, figs. 2, 2*a*–*b*.)

See Bull. U. S. Geol. Survey, No. 30, p. 87.

Formation and locality.—Lower Cambrian; Conglomerate limestone, on the ridge east of the city of Troy, N. Y.

Nat. Mus. Cat. Invert. Foss., 15306.

ETHMOPHYLLUM Meek.

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 75.

ETHMOPHYLLUM WHITNEYI Meek.

(Pl. LV, figs. 1, 1*a*–*e*.)

See Bull. U. S. Geol. Survey, No. 30, p. 81.

In addition to this species a second has been discovered in the material from Silver Peak; and the *Archæocyathus marianus* Roemer[1] proves to belong to the same genus.

Formation and locality.—Lower Cambrian; Silver Peak, Western Nevada. The species occurs in a limestone and calcareous shale, associated with *Spirocyathus atlanticus*, *Hyolithes princeps*, *Olenellus gilberti*, etc.

Nat. Mus. Cat. Invert. Foss., 15307.

ETHMOPHYLLUM MEEKI Walcott.

(Pl. LV, figs. 2, 2*a*–*c*.)

Ethmophyllum meeki, Walcott, 1889, U. S. Nat. Mus., Proc., vol. 12, p. 34.

This form differs from *E. whitneyi*, with which it is associated,

[1] Lethæa geonostica, vol. 1, 1880, p. 301.

in having stronger radiating septa, numerous dissepiments, and large pores in the outer wall.

Formation and locality.—Lower Cambrian; Silver Peak, Nevada.

Nat. Mus. Cat. Invert. Foss., 18358.

TRAILS, BURROWS, AND TRACKS OF ANIMALS.

As far as known to me, there are no true Algæ found in the rocks of the Lower Cambrian, except possibly in New Brunswick. That such forms existed there can scarcely be any doubt, but, after a careful study of all the reported species, I think they can be referred to trails of worms or mollusks with much more propriety than to the Algæ.

The trails, burrows, and tracks are referred to the following genera and species:

PLANOLITES Nicholson.

Planolites Nicholson, 1873. Proc. Roy. Soc. London, p. 289.

PLANOLITES ANNULARIUS Walcott.

(Pl. LX, fig. 5.)

Planolites annularius, Walcott, 1889, U. S. Nat. Mus., Proc., vol. 12, p. 34.

The cast of a burrowing worm that shows numerous annulations.

Formation and locality.—Lower Cambrian. At the Reynolds Inn locality of *Olenellus* (*M.*) *asaphoides*, one mile west of North Greenwich, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 18360.

PLANOLITES CONGREGATUS Billings.

(Pl. LXI, fig. 1.)

Palæophycus congregatus Billings, 1861. Bull. Geol. Survey Canada, p. 2.

This and the following species were referred to the Algæ by Mr. Billings. The reference may be correct, but these forms impress me as being the casts of worm-borings; and there is nothing in the specimens to indicate their vegetable origin. This form of cast is found in sandy argillaceous deposits, all through the sedimentary rocks.

PLANOLITES VIRGATUS Hall (sp).

(Pl. LXI, fig. 5.)

Palæophycus virgatus Hall, 1847, Pal., N. Y., vol. 1, p. 263, pl. 70, fig. 1.
Palæophycus incipiens Billings, 1861. Bull. Geol. Survey Canada, p. 2.

This character of worm-boring is common in the sandy shales near Swanton, and at Parker's quarry, Georgia, Vermont, where it is associated with *Olenellus* (*M.*) *asaphoides*. The type specimens described by Professor Hall are from the same geologic horizon as

those to which Mr. Billings gave the name *P. incipiens*, and I think there is no good reason for separating them as two species.

HELMINTHOIDICHNITES Fitch.

Helminthoidichnites Fitch, 1850. Trans. N. Y. State Agric. Soc. for 1849, p. 868.
Compare *Nemertites* Nicholson, 1873. Proc. Roy. Soc. London, p. 289.

HELMINTHOIDICHNITES MARINUS Emmons (sp.).

(Pl. LX, fig. 1.)

Goraia marina Emmons, 1844. Taconic System, p. 67, pl. 1, fig. 2. Idem, 1846. Agric, N. Y., vol. i, p. 68, Pl. xiv, fig. 2. Idem, Hall, 1847, Pal. N. Y., vol. 1. p. 264, pl. 71, figs. 1, 2.
Palæophycus rectus Fitch, 1850. Trans. N. Y. State Agric. Soc. for 1849, p. 862.
Compare *Fucoides flexuosa* Emmons, 1844. Taconic System. pl. 5, fig. 3.
Helminthoidichnites tenuis Fitch, 1850. Trans. N. Y. State Agric. Soc. for 1849, p. 866, figure in text.

Dr. Fitch proposed the genus Helminthoidichnites for "*tracks resembling those of worms,*" and figured this species as a very narrow trail on an arenaceous shale. I have seen fragments of a similar trail in the arenaceous slates of the Olenellus zone and also in the Upper Cambrian shales of the Grand Cañon of the Colorado, Arizona. Those from the latter afford the best illustration, and a figure is given of a small portion of the surface of the arenaceous shale showing the trail upon it.

This type of borings or trails is very abundant in the purple, green, and dark slates and the arenaceous shales of the Olenellus zone. Similar trails may have been made by many different species during all the geologic epochs, down to the present day.

Fig. 4, Pl. LXII, illustrates a rather broad trail or boring; Fig. 3 a narrow form where a portion is stained with oxide of iron; Fig. 1 numerous trails crossing each other at various angles; Fig. 2 a cluster of narrow trails separated by numerous breaks in their course.

The specimens figured by Emmons and Hall show the curvings and crossings much more completely than any in the collections accessible to me.

SCOLITHUS Haldeman.

Scolithus Haldeman, 1840. Suppl. to No. 1 of Monog. of the Limniades, etc., p. 3.

SCOLITHUS LINEARIS Haldeman.

(Pl. LXIII, figs. 1, 1*a*–*c*.)

Scolithus linearis Haldeman, 1840. Suppl. to No. 1 of Monog. of the Limniades. etc., p. 3.
Scolithus linearis Hall, 1847. Pal. N. Y., vol. i, p. 2, Pl. I, Figs. 1*a*–*c*. Billings, 1861. Bull. Geol. Survey Canada, p. 2. Idem, 1862. Geol. Vermont, vol. 2, p. 943. Idem, 1865. Pal. Foss., vol. i, p. 2.

This form appears to range through the Cambrian. Exactly similar holes are found in the sandstones of the Potsdam sandstone. It

is not probable that the same species of animal made them in the two epochs, but we have nothing to guide us in separating them.

Formation and locality.—Lower Cambrian. L'Anse au Loup, Straits of Belle Isle, Labrador.

CRUZIANA d'Orbigny.

Bilobites DeKay, 1823. Ann. Lyc. Nat. Hist., New York, vol. 1, pp. 45–49. Not *Bilobites* Linn., 1775.
Cruziana d'Orbigny, 1842. Voyage d'Amérique merid. III.
Rusophycus Hall, 1852. Pal. N. Y., vol. ii, p. 23.

CRUZIANA sp.?

(Pl. LXIV, figs. 1, 1*a*–*e*; Pl. LXV, figs. 1, 1*a*, 2; Pl. LXVI, figs. 1, 1*a*, *b*.)

A careful examination of a large series of specimens of the trails and burrows referred to Cruziana, from a single layer of sandstone, leads me to consider that they are all of animal origin, and that many of the so-called species were formed by one species of animal. Also that specific differences in the animals making them would not generally be shown in the casts of the burrows and trails.

Fig. 1, on Pl. LXIV, shows the form and surface markings of a cast of the under surface of the animal when it was at rest. Fig. 1, Pl. LXV, shows a succession of similar casts made by the forward movement of the animal. Fig. 2, Pl. LXV, preserves the form of several successive casts of the animal, and at the same time the form of trail made when it was in more rapid motion than when the cast represented by Fig. 1, Pl. LXV, was formed. From Fig. 1, Pl. LXV, it is but a step to the form represented by Fig. 2 of the same plate and the narrow form, Fig. 1*b*, Pl. LXIV, Fig. 1, Pl. LXVI. The latter approach very closely to the genus Arthrophycus of Hall.

In a paper on the genus Cruziana and allied forms, I hope to give my reasons for considering them as burrows and trails of animals and not the casts of fucoids.

HYDROZOA.

PHYLLOGRAPTUS Hall.

PHYLLOGRAPTUS?? CAMBRENSIS, n. sp.

(Pl. LIX, figs. 3, 3*a*.)

Diplograptus secalinus Emmons, 1856. Am. Geol., vol. 1, part 2, pl. 1., fig. 11.
Diplograptus simplex Walcott, 1886. Bull. U. S. Geol. Surv., No. 30, p. 92, pl. 11, figs. 4, 4*a*.
Phyllograptus ? simplex, Walcott, 1889. Am. Jour. Sci., 3d ser., vol. 37, p. 388.

A note on this species in Bulletin 30 contains the following statement: "Dr. Emmons originally applied the name *Fucoides simplex*

(Taconic System, 1844, Pl. V, fig. 1; Agric. Rept., N. Y., pt. 5, 1846, Pl. XVII, fig. 1), to a species previously named by Prof. Amos Eaton (see Twentieth Rept., N. Y. State Mus. Nat. Hist., 1868, p. 268), as *Fucoides secalinus.* Subsequently he referred the species named by him to Eaton's *F. secalinus*, calling it *Diplograptus secalinus*, gave a description as above, and at the same time figured another species which we have found in the fine argillaceous shales of Parker's ledge. For this I have decided to use Emmons's name *simplex*, the name *D. secalinus* being restricted to the species from the Hudson River group, as described by Prof. Hall (Pal. of N. Y., vol. 1, 1847, p. 267)." (Pp. 92, 93.)

A revision of the synonymy leads me to the conclusion that as the name *simplex* was applied to the species *Fucoides simplex* by Emmons, which is a synonym of *Fucoides secalinus* of Eaton, that the name *simplex* can not longer be used for the second species, and I therefore propose the name *cambrensis.* The generic reference is without value, owing to the imperfection of the material for study.

Formation and locality.—Lower Cambrian, Georgia formation; Parker's quarry, Georgia, Franklin County, Vermont.

Nat. Mus. Cat. Invert. Foss., 15314.

CLIMACOGRAPTUS Hall.

CLIMACOGRAPTUS?? EMMONSI Walcott.

(Pl. LIX, fig. 4.)

See Bull. U. S. Geol. Survey, No, 30, 1886, pp. 93, 94.

Type in collection of E. Hurlbert, Esq., Utica, N. Y.

DACTYLOIDITES Hall.

DACTYLOIDITES ASTEROIDES Fitch.

(Pl. LVII. Pl. LVIII, figs. 1, 1*a*.)

Buthotrephis ? asteroides Fitch, 1850. Trans. New York State Agric. Soc., vol. 9, for 1849, p. 863.

Dactyloidites bulbosus Hall, 1886. Thirty-ninth Ann. Rep., Reg. State Mus. Nat. Hist., New York, for 1885, p. 160; Pl. 11, Figs. 1, 2.

The original description and figure illustrating this species are imperfect, but to any one acquainted with the form as shown on the slabs of slate, there is little doubt of the identity of the species described by Dr. Fitch and that described by Prof. Hall. The type specimen had five divisions or rays, and the one described by Prof. Hall has six. On a large slab now in the State Museum, at Albany,

both five and six rayed specimens occur. Some of the specimens show the structure figured by Dr. Fitch, and others that seen on the plate published by Prof. Hall. Dr. Fitch classed the species with plants, indicating by the generic name a fucoid. Prof. Hall compares it with the graptolites, but thinks the form is referable to the sponges or marine algæ. Neither author gives its correct stratigraphic position.

A comparison with figures given by Nathorst of Medusites, suggests that the problematical forms under consideration are compressed impressions of the mouth and gastric cavity of a species of Medusa. The scope of the present paper does not permit of a full discussion of the evidence favoring this view. It may be presented in the future.

I found *Olenellus* (*M.*) *asaphoides*, *Microdiscus speciosus* and other species of Lower Cambrian fossils in a thin bed of limestone interbedded in the slate at the quarry from which the slabs containing the impressions of this species were obtained.

Formation and locality.—Lower Cambrian; Middle Granville, Washington County, New York.

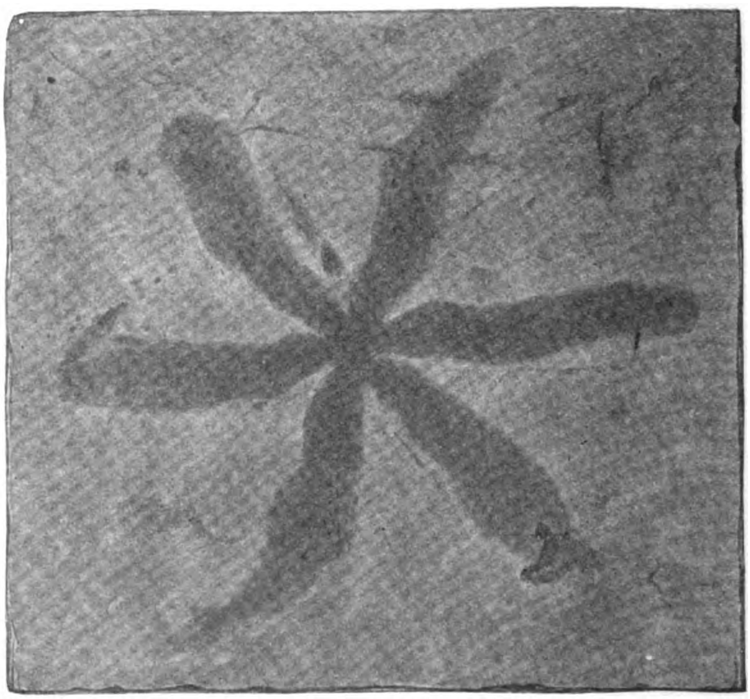

FIG. 61.—*Dactyloidites asteroides*. Specimen on a slab of slate from Middle Granville, N. Y. The six rays are narrow, as in the type figured by Dr. Fitch.

ECHINODERMATA.

EOCYSTITES Billings.

(Pl. LX, fig. 3.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 94.

A few plates of a cystidian character are all that are known of the Echinodermata in the Lower Cambrian. The generic reference is provisional.

Formation and locality.—Lower Cambrian; Georgia, Vermont, and Pioche, Nevada.

Nat. Mus. Cat. Invert. Foss., 15317.

BRACHIOPODA.

LINGULELLA Salter.

LINGULELLA CÆLATA Hall (sp.)

(Pl. LXVII, figs. 1, 1*a–e*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 95.

Formation and locality.—Lower Cambrian; conglomerate limestone on the ridge east of the city of Troy, N. Y.; also, one mile south of Schodack Landing, in Columbia County, New York.

Nat. Mus. Cat. Invert. Foss., 15325.

LINGULELLA ELLA H. & W.

(Pl. LXVII, figs. 2, 2*a–e*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 97.

This species occurs in the Lower and Middle Cambrian zones, in Nevada. The illustrations are taken from the specimens found in the Middle Cambrian zone, as they are there more numerous and better preserved.

Formation and locality.—Lower and Middle Cambrian; near Pioche, Nevada.

Nat. Mus. Cat. Invert. Foss., 15319.

LINGULELLA GRANVILLENSIS Walcott.

(Pl. LXVII, figs. 4, 4*a–d*.)

Lingulella granvillensis Walcott, 1887. Am. Jour. Sci., 3d ser., vol. 34, pp. 188, 189, Pl. i, Figs. 15–15c.

Shell small, elongate ovate, margins subparallel for a short distance at the widest portion about midway of the shell, broadly rounded in front, ventral valve attenuate toward the beak; dorsal

valve ovate and rounded at the beak. General surface depressed convex. Surface marked by fine concentric lines and more rarely, fine radiating lines.

The cast of the interior of the ventral valve shows four narrow elongate scars, radiating from the beak toward the front margin.

A cast of the interior of a dorsal valve shows fine vascular markings and a well marked median groove, also faint impressions of the anterior adductor muscular scars and also what may have been the adjustor muscular scars.

This species occurs abundantly in the upper portion of the Olenellus zone of Washington County, N. Y. It is the representative in the Lower Cambrian of *Lingulella dawsoni* (Bull. 10, U. S. Geol. Survey, 1884, p. 15), of the Middle Cambrian. It may also be compared with *Lingulella ferruginea*, which ranges from the Harlech beds through the Menevian and probably into the period of the Lingula flags (Brit. Foss. Brach., vol iii, p. 337). Dr. G. Linnarsson figures a closely related species from the Paradoxides beds of Sweden (Brach. Par. Beds of Sweden, Pl. III, Figs. 24–28).

Formation and localities.—Lower Cambrian. Limestones interbedded in the shaly slates, 2 miles south of North Granville; by the roadside a little west of the bridge crossing the Poultney River at Low Hampton; and on the roadside north of school-house No. 4, in the northeast part of Whitehall, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17440.

ACROTRETA Kutorga.

ACROTRETA GEMMA Billings.

(Pl. LXVII, figs. 5, 5*a–e*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 98.

The specimens of this species, associated with *Olenellus gilberti*, at Pioche, Nev., are larger and usually more depressed than those from the Upper Cambrian strata of Montana. The range of variation among the latter includes the Lower Cambrian form.

Nat. Mus. Cat. Invert. Foss., 15343.

IPHIDEA Billings.

IPHIDEA BELLA.

(Pl. LXVII, fig. 6.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 100.

ACROTHELE Linnarsson.

ACROTHELE SUBSIDUA White.

(Pl. LXX, figs. 1, 1*a–c*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 108.

This species is abundant in association with *Olenellus gilberti*, near

Pioche, Nev., and it also occurs at Antelope Springs in association with the Middle Cambrian fauna.

Fragments of a closely related form occur in the higher Olenellus horizon of Washington County, N. Y.; and the *Acrothele matthewi* Hartt, of the Middle Cambrian, New Brunswick, is a closely allied, if not identical, species.

Nat. Mus. Cat. Invert. Foss., 15347.

KUTORGINA Billings.

KUTORGINA CINGULATA Billings.

(Pl. LXIX, figs. 1, 1*a–h*.)

See Bull. U. S Geol. Survey, No. 30, 1886, p. 102.

Nat. Mus. Cat. Invert. Foss., 15337.

KUTORGINA LABRADORICA Billings.

(Pl. LXIX, figs. 3, 3*a–b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 104.

In addition to the localities mentioned in Bulletin 30, there is to be added Topsail Head limestone, Conception Bay, S. E. Newfoundland, and the Vermont localities are to be dropped as the shells from them are referred to the variety *swantonensis*.

Nat. Mus. Cat. Invert. Foss., 18309.

KUTORGINA LABRADORICA var. SWANTONENSIS Walcott.

(Pl. LXIX, fig. 2, 2*a–b*.)

Kutorgina labradorica, var. *swantonensis*, Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, p. 36.

A comparison of a series of specimens of *K. labradorica*, from Newfoundland, with a series from near Swanton, Vt., show constant differences. The striæ on the Swanton shells are finer and more regular, and the valves are less transverse in proportion to the length, and the beak of the ventral valve is less elevated.

Formation and locality.—Lower Cambrian. East of Swanton and Highgate Springs, Vt.

Nat. Mus. Cat. Invert. Foss., 15329.

KUTORGINA PANNULA White. (sp.)

(Pl. LXIX, figs. 5, 5*a–f*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 105.

This species ranges from the Olenellus zone to the Middle Cambrian in Nevada. A form that appears to be specifically identical, occurs in the upper part of the Olenellus zone, in Washington County,

N. Y., and also in the Sillery conglomerate on the south shore of the Island of Orleans.

Nat. Mus. Cat. Invert. Foss., 15332.

KUTORGINA PROSPECTENSIS Walcott.

(Pl. LXIX, figs. 4, 4*a*.)

See Bull. U. S. Geol. Survey, No. 30, p. 106.
Nat. Mus. Cat. Invert. Foss., 15335.

LINNARSSONIA Walcott.

Am. Jour. Sci., 3d ser., vol. 29, 1885, p. 114.

LINNARSSONIA SAGITTALIS var. TACONICA Walcott.

(Pl. LXVIII, figs. 1, 1*a*—*d*.)

Linnarssonia taconica Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, pp. 189, 190, Pl. i, figs. 18–18*d*.

Shell small, rarely exceeding 3^{mm} in length or breadth, usually circular or transversely broad oval. Ventral valve moderately convex; apex excentric; dorsal valve depressed convex; beak obtusely pointed, marginal; surface of the valves marked by fine lines of growth.

In the interior of the ventral valve, near the posterior margin, oblique scars occur, one on each side of the raised rim surrounding the foraminal opening in allied species. From a point of the foraminal rim a narrow depression extends obliquely outward and forward on each side, so as to inclose a Λ-shaped elevation, that is strongly marked in casts of the interior valve. The interior of the dorsal valve shows two large oval scars near the posterior margin, separated by a low ridge that extends over three-fourths of the distance to the front margin.

This species is related to both *L. transversa* and *L. sagittalis.*[1] It differs chiefly in the characters of the interior of the dorsal valves. As yet none of the specimens have shown the ventral valve to be perforate; this is owing probably to the minute size of the opening and the imperfection of the specimens which have been examined.

This is the first instance known to me of the occurrence of this genus in association with the Lower Cambrian faunas, as it is essentially a Middle Cambrian type both in New Brunswick, Newfoundland, Sweden and Wales.

This variety occurs in the upper part of the Olenellus zone, in Washington County, N. Y., and, with the exception of the variation in size, it is essentially identical with *L. sagittalis* Salter, *L. transversa* Hartt, and *L. misera* Billings, of the Paradoxides zone.

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[1] Am. Jour. Sci., 3d series, vol. 9, pp. 114–117.

Formation and localities.—Lower Cambrian; limestones interbedded in the shaly slates at Rock Hill school-house (No. 8), near North Greenwich; 1½ miles west of North Greenwich; lowest fossiliferous horizon on D. W. Reid's farm, 1½ miles west of North Greenwich; west summit of Bald Mountain, in the town of Greenwich; 2 miles south of North Granville; on the roadside just west of Low Hampton crossing of the Poultney River; and 1 mile south of Shushan, all in Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17441.

OBOLELLA Billings.

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 109.

OBOLELLA ATLANTICA Walcott.

(Pl. LXXI, figs. 1, 1*a*–*c*.)

Obolella atlantica Walcott, 1889, U. S. Nat. Mus. Proc., vol. 12, p. 36.

This is a small species of Obolella that occurs in great abundance in Newfoundland and also less frequently at North Attleborough, Mass.[1] It is of the type of *Obolella crassa*, but differs in the details of the interior surfaces and the average smaller size.

Formation and locality.—Lower Cambrian; Manuel's Brook, Topsail and Brigus Heads, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18322.

OBOLELLA CIRCE Billings.

(Pl. LXXI, figs. 3, 3*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 118.

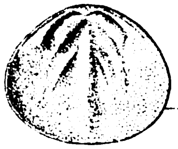

FIG. 62.—*Obolella circe?*. Interior of a dorsal valve from St. Simon. This shell is doubtfully referred to the species.

Nat. Mus. Cat. Invert. Foss., 14892.

OBOLELLA CHROMATICA Billings.

(Pl. LXXI, figs. 2, 2*a*, *b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 112.

Nat. Mus. Cat. Invert. Foss., 14891.

[1] Bull. Mus. Comp. Zool., Harvard College, vol. 16, 1888; Prelim. Descp. North Attleborough Fossils, p. 27.

Obolella crassa Hall (sp.).

(Pl. LXXI, figs. 4, 4*a–f*.)

See Bull. U. S. Geol. Survey, 1886, p. 114.

In addition to the localities mentioned in Bulletin 30, the species is now known to occur near North Attleborough, Mass.[1]

Nat. Mus. Cat. Invert. Foss., 15347.

Obolella gemma Billings.

(Pl. LXXI, figs. 5, 5*a—c*. Pl. LXXII, figs. 2, 2*a*.)

See Bull. U. S. Geol. Survey, p. 116.

Nat. Mus. Cat. Invert. Foss., 14889.

Obolella nitida Ford.

(Pl. LXXII, fig. 1.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 118.

This species has been found at several localities in Washington County, N. Y., but the specimens have not added to our knowledge of the species.

Nat. Mus. Cat. Invert. Foss., 15353.

ORTHIS Dalman.

Orthis highlandensis Walcott.

(Pl. LXXII, figs. 5, 5*a*, *b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 119.

Nat. Mus. Cat. Invert. Foss., 15355.

Orthis salemensis Walcott.

(Pl. LXXII, figs. 6, 6*a*.)

Orthis salemensis Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, pp. 190, 191, Pl. i, figs. 17, 17*a*.

Shell about the average size of the Cambrian species of the genus. Transversely subquadrilateral; front broadly rounded and slightly sinuate midway; hinge line as long as the greatest width of the shell

Ventral valve convex, most elevated about one-fourth the distance from the beak to the anterior margin; beak small and incurved to the margin of the medium sized area; the surface of the area and the foramen have not been observed; mesial sinus broad and shallow, it

[1] Bull. Mus. Comp. Zool., Harvard College, vol 16, 1888.: Prelim. Descp. North Attleborough Fossils, p. 27.

is marked by a low median rib and laterally by two costæ on each side, a third appearing just outside the sinus.

The dorsal valve, associated in the same hand specimen of limestone, is slightly more convex; frontal margin with a rather deep sinuosity to receive the projection of the ventral valve; median fold broad and but slightly elevated, marked by two or three low costæ; the beak appears in the broken specimen in the collection to be scarcely elevated above the surface of the shell, and to terminate at the cardinal margin; area unknown.

The surface of both valves is marked by fine concentric lines of growth, and low, rounded costæ, varying in number from six to seven, as in the specimens figured, to twelve or fourteen in other specimens.

In the broad costæ and the general aspect of the shell this species is unlike any known to me from the Cambrian.

Formation and localities.—Lower Cambrian; limestones interbedded in the shaly slates one and one-half miles south of Salem; one mile south of Shushan, and near Rock Hill school-house (No. 8), Greenwich, Washington County, N. Y. It is also present in limestone bowlders of the Cambrian conglomerate at Metis, on the St. Lawrence, below Quebec. *Olenellus* sp. *Hyolithellus micans*, etc., occur in association with it.

Nat. Mus. Cat. Invert. Foss., 17443.

ORTHISINA d'Orbigny.

ORTHISINA FESTINATA Billings.

(Pl. LXXII, figs. 7, 7*a*, *b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 120.
Nat. Mus. Cat. Invert. Foss., 15359.

ORTHISINA ORIENTALIS Whitfield.

(Pl. LXXII, fig. 8.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 120.
Nat. Mus. Cat. Invert. Foss., 15360.

ORTHISINA TRANSVERSA Walcott.

(Pl. LXXII, figs. 9, 9*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 121.
Nat. Mus. Cat. Invert. Foss., 15361.

CAMARELLA Billings.

CAMARELLA ANTIQUATA Billings.

(Pl. LXXII, fig. 3.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 122.
Nat. Mus. Cat. Invert. Foss., 15363.

CAMARELLA ? MINOR Walcott.

(Pl. LXXII, figs. 4, 4*a–d*.)

Camarella minor Walcott, 1889, U. S. Nat. Mus. Proc., vol. 12, p. 36.

Shell small, moderately convex; valves about equal in depth. Ventral valve convex on the umbo, with the beak slightly incurved; cardinal slopes nearly straight from the beak to the rounded sides; the posterior or umbonal third of the valve is usually more or less tumid, a ridge of growth separating it from the anterior portion of the shell. Dorsal valve shorter than the ventral valve; transversely oval, most prominent at the umbo; beak very small and terminating at the cardinal margin.

The casts of the surface show only concentric lines of growth. Usually an elevated line or ridge separates the tumid umbonal portion of the shell from the anterior part.

The casts of the interior of the ventral valve have a small pit just in front of the termination of the beak, from which two narrow depressions extend forward and separate off a short, narrow, central ridge and two lateral pointed projections, which extend forward to the line of the base of the central ridge and are defined, laterally, by sharp, narrow depressions. This form indicates that two lamellæ or plates extended out from the beak on each side of a narrow central depression and then curved outward toward the margin, somewhat as in Pentamerus. In one cast two slight ridges extend from the base of the lateral projections a short distance anteriorly. In the interior of the dorsal valve a transverse depression, just in front of the beak, corresponds to a transverse ridge on the interior of the valve.

Owing to the imperfect casts of the interior the generic reference to Camarella is tentative.

In company with Prof. William B. Dwight I found this species associated with heads and fragments of a trilobite that is referred to *Olenellus asaphoides*.

Formation and locality.—Lower Cambrian; in the quartzitic sandstones of Stissing Mountain, near Stissingville, Dutchess County, New York.

LAMELLIBRANCHIATA.

The presence of two shells that can be referred to this class is of unusual interest, as none are met with above until the base of the Lower Silurian (Ordovician) is reached. There is some doubt about the reference of *Fordilla troyensis*, as it may possibly be founded on the valves of a small crustacean. *M. prisca* appears to be a true lamellibranchiate shell.

FORDILLA Barrande.

FORDILLA TROYENSIS Barrande.

(Pl. LXXIII, figs. 1?, 2, 2*a*–*c*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 125.

The cast of a shell closely allied to this was found near North Attleborough, Mass., by Prof. N. S. Shaler.[1]

Nat. Mus. Cat. Invert. Foss., 15372.

MODIOLOIDES Walcott.

MODIOLOIDES PRISCA Walcott.

(Pl. LXXIII, fig. 3.)

Modiolopsis ?? prisca Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, pp. 191, 192, Pl. i, Fig. 19.

The only specimen of the species known to me is the cast of a right (?) valve, 2^{mm} in length. It is transversely oval in outline and rather strongly convex; the beak is subcentral and curves toward the hinge line, but does not reach it; an oval muscular scar is situated just within the pallial line, at the supposed anterior end; pallial line simple, continuous as far as observed.

The minute size and the fact that we have only the cast of the interior of the valve, render it very difficult to determine the correct generic relations of the shell. The nearly central position of the beak distinguishes it from all known species of Modiolopsis; while the muscular scar and pallial line, with the oval form, relates it to *Modiolopsis curta* of the Hudson River formation. The discovery of the character of the hinge line may place it in a genus of the Arcadæ; but at present I do not wish to state more than that I think it is undoubtedly a lamellibranchiate shell. With the possible exception of *Fordilla troyensis,* which possibly may be the shell of some Estheria-like crustacean, I know of no other true lamellibranchiate shell in the Cambrian system of America, as defined in 1886. (Am. Jour. Sci., 3d series, vol 32, p. 147.)

Formation and locality.—Lower Cambrian; limestone interbedded in shaly slate, on the roadside north of school-house No. 4, in the northeast part of Whitehall, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17445.

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[1] Bull. Mus. Comp. Zool., Harvard College, vol. 16, 1888, p. 28.

GASTEROPODA.

HELENIA Walcott.

Helenia Walcott, 1889, U. S. Nat. Mus. Proc., vol. 12, p. 39.

Shell an elongate, narrow, flattened, curved tube; transverse section and aperture elliptical. Surface marked by transverse, concentric, imbricating lines of growth.

HELENIA BELLA Walcott.

(Pl. LXXVIII, figs. 4, 4*a–b*.)

Helenia bella Walcott, 1889, U. S. Nat. Mus. Proc., vol. 12, p. 39.

Shell an elongate, narrow, flattened, curved tube. The plane of the flattened surfaces is slightly twisted, so as to throw the lateral margins about one quarter of a turn around and to incline the upper and lower faces nearly 45° at one extremity as compared with the other. The curvature is nearly semicircular. The cross section is an elongated ellipse. The form of the aperture of the larger extremity, as indicated by the striæ of growth, has the peristome arching forward on one of the flattened sides and curving slightly backward on the opposite side. As far as I am able to determine, the shell was open at the smaller end, as in Dentalium, or the extremity was decollated in all the specimens collected. I am inclined to think that it was open at both ends, and hence should be referred to the Dentalidæ.

Surface marked by irregular, transverse or concentric, imbricating lines of growth that vary in number and size on the same specimen and in different specimens.

Helenia bella is provisionally referred to the Dentalidæ on account of its form and the apparent opening at both extremities.

Formation and locality.—In a pinkish colored limestone of Lower Cambrian age, in association with *Hyolithes princeps, Olenellus* (*H.*) *bröggeri*, etc., in railway cut north of Manuel's Brook, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18324.

SCENELLA Billings.

SCENELLA ? CONULA Walcott.

(Pl. LXXIII, figs. 4, 4*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 127.
Nat. Mus. Cat. Invert. Foss., 15367.

SCENELLA RETICULATA Billings.

(Pl. LXXIII, figs. 9, 9*a–d*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 125.

This species was found in great abundance in association with *Olenellus* (*H.*) *bröggeri*, near Manuel's Brook, Conception Bay, New-

foundland. It varies very much in form and size of the aperture, owing probably to accidents of growth. It has also been found near North Attleborough, Mass., by Prof. N. S. Shaler.[1]

Nat. Mus. Cat. Invert. Foss., 18321.

SCENELLA RETUSA Ford.

(Pl. LXXIII, figs. 6, 6*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 126.

Type in collection of S. W. Ford.

SCENELLA? VARIANS Walcott.

(Pl. LXXIII, figs. 5, 5*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 127.

Nat. Mus. Cat. Invert. Foss., 15370.

SCENELLA sp.?

A depressed conical shell occurs in the form of casts in the reddish brown sandstones, east of Lansingburgh, N. Y., that differs from all described species from the Cambrian. It is most nearly related to *S. varians*, but owing to the imperfection of the material it is not thought best to give it a specific name.

STENOTHECA Salter.

STENOTHECA? ELONGATA Walcott.

(Pl. LXXIV, figs. 9, 9*a*–*b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 129.

Nat. Mus. Cat. Invert. Foss., 15364.

STENOTHECA ? RUGOSA Hall.

(Pl. LXXIV, figs. 1, 1*a*–*i*.)

See Bull. U. S. Geol. Survey, No. 30, p. 128.

This species varies considerably in form and surface characters. Several of the more srongly marked varieties are given names as follows:

Var. abrupta, S. & F., Figs. 6, 6*a*.
Var. acuta-costa, n. var., Figs 2, 2*a*, *b*.
Var. erecta, n. var., Fig. 4.
Var. levis, n. var., Figs. 5, 5*a*.
Var. paupera, Billings, Figs. 3, 7.

The varieties *abrupta* and *paupera* also occur near North Attleborough, Mass.[2]

Nat. Mus. Cat. Invert. Foss., 15365, 18310, 18311, 18312, 18313.

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[1] Bull. Mus. Comp. Zool., Harvard College, vol. 16, 1888, p. 29.

[2] Bull. Mus. Comp. Zool. Harvard College, vol. 16, p. 29.

STENOTHECA CURVIROSTRA S. & F.

(Pl. LXXIV, fig. 10.)

Stenotheca curvirostra Shaler & Foerste, 1888. Bull. Mus. Comp. Zool., vol. 16, p. 30, Pl. i, Fig. 8.

"Shell small, rather elongate; the lower part gently curved, the curvature more marked, especially at the beak; the beak always considerably elevated above the aperture of the shell. The transverse ribs are narrow and sharp; from ten to eighteen are found on a single shell; the interspaces are broad and flat. The longitudinal striæ are fine and closely set. Diameter of the aperture of the shell in the largest specimen found, 4^{mm}; height of the shell, 5^{mm}.

"*Locality and position.*—Station No. 2, North Attleborough, Mass.; Cambrian; 5 specimens."

Type in collection of Prof. N. S. Shaler.

PLATYCERAS Conrad.

PLATYCERAS PRIMÆVUM Billings.

(Pl. LXXIV, figs. 11, 11*a*.)

See Bull. U. S. Geol. Survey, No. 30, p. 130.

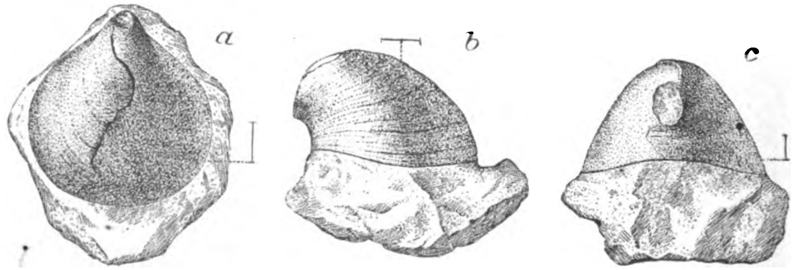
This little shell appears to have a wide geographic distribution and a great vertical range, as a form, apparently identical with it, occurs in the Upper Cambrian limestones of New York. Since Bulletin 30 was written it has been found at North Attleborough, Mass.,[1] and at Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 15371.

PLATYCERAS DAWSONI, n. sp.

Shell small, ventricose; apex unknown. Body expanding rapidly from the base of the apex to the nearly circular aperture; peristome broadly sinuate at the posterior margin. Surface marked by a few concentric lines of growth.

This little shell is a strongly marked form. It is referred to Platyceras on account of the incurving toward the apex and the sinuosity of the posterior margin.



FIGS. 63 *a, b, c*.—*Platyceras dawsoni*. Dorsal, lateral and posterior views of the type specimen. Collection Peter Redpath Museum, McGill College, Montreal, Canada.

[1] Bull. Mus. Comp. Zool., Harvard College, Mass., vol. 16, p. 30.

Formation and locality.—Lower Cambrian; associated with Olenellus at St. Simon, province of Quebec, Canada.

STRAPAROLLINA REMOTA Billings.

(Pl. LXXIV, figs. 13, 13*a*.)

See Geol. Survey, Canada; Pal. Foss., vol. 2, pt. 1, 1874, p. 70, Fig. 38.

Prof. J. F. Whiteaves, paleontologist to the Geological Survey of Canada, informs me that the type specimen of this species can not be found. He kindly sent a fragment showing the outer whorl. On this longitudinal lines and concentric striæ are shown, in addition to the characters given the species by Mr. Billings.

PLEUROTOMARIA De France.

PLEUROTOMARIA (RAPHISTOMA) ATTLEBORENSIS S. & F.

(Pl. LXXIV, figs. 12, 12*a*.)

Pleurotomaria (Raphistoma) attleborensis Shaler & Foerste. Bull. Mus. Comp. Zool., Harvard College, vol. 16, pp. 30, 31, Pl. 2, Fig. 11.

"Shell small, flattened, composed of three whorls. The first whorl is very small; the succeeding ones increase rapidly in size. The surface in general slopes at a low angle from the apex of the shell to the sides. In the last whorl of the cast the outside margin of the coil thickens a little, forming an indistinct border along the margin of the shell, which becomes more evident as it approaches the orifice. The edge of the whorl is compressed and rather narrowly rounded. The surface of the shell is marked by fine, transverse, closely set striæ, which apparently are directed backward toward the earlier formed parts of the shell, but in reality indicate various stages of growth of the shell. The internal cast does not show these fine striæ, but broader and more widely separated elevations, having the same direction as the striæ. The diameter of the shell is 3.2^{mm}; the height is a little less than 1^{mm}. Owing to the shape of the shell it is difficult to measure its height accurately.

"*Locality and position.*—Station No. 1, North Attleborough, Mass.; Cambrian; one specimen. The discovery of another coiled gasteropod in this division of the Cambrian of America is of interest, and makes the sudden influx of coiled genera in the Upper Cambrian less inexplicable."

This is one of the most interesting forms found at the locality, discovered by Prof. N. S. Shaler, near North Attleborough, Mass. It appears to be a true representative of the Pleurotomaridæ in the Lower Cambrian.

Type in the collection of Prof. N. S. Shaler.

PTEROPODA.

HYOLITHES Eichwald.

HYOLITHES AMERICANUS Billings.

(Pl. LXXV, figs. 2, 2*a–f*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 132.

Fig. 64.—*Hyolithes americanus.* Dorsal surface. Natural size.

On the dorsal surface of some well preserved specimens from St. Simon, a central longitudinal ridge occurs that is very much like that on *H. billingsi*, from Nevada. The two species are closely related. The character of the median ridge is shown in Fig. 64.

Found also at North Attleborough, Mass., and at Manuel's Brook, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 15388.

HYOLITHES BILLINGSI Walcott.

(Pl. LXXV, figs. 1, 1*a–e*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 134.

Found also at North Attleborough, Mass.

Nat. Mus. Cat. Invert. Foss., 14903.

Among some specimens, from St. Simon, Canada, received from Sir William Dawson, there is one of this species showing three transverse septa. The septa are strong, apparently flat and imperforate.

Nat. Mus. Cat. Invert. Foss., 14884.

HYOLITHES COMMUNIS Billings.

(Pl. LXXVII, figs. 3, 3*a–g*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 136.

Fig. 65.—*Hyolithes communis*, Bill. Natural section of a portion of the tube in which three transverse septa are shown. Collection Peter Redpath Museum, McGill College, Montreal, Canada.

HYOLITHES COMMUNIS var. EMMONSI Ford.

(Pl. LXXVII, figs. 4, 4*a*–*b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 137.

Hyolithes inæquilateralis Foerste, 1889. Boston Soc. Nat. Hist. Proc., vol. xxiv, p. 7.

This species has been found near North Attleborough, Mass., since the publication of the list of localities in Bulletin 30.

Nat. Mus. Cat. Invert. Foss., 15386.

HYOLITHES IMPAR Ford.

(Pl. LXXVII, figs. 1, 1*a*–*f*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 139.

This species also occurs in association with the Olenellus fauna at Manuel's Brook, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 15391.

HYOLITHES PRINCEPS Billings.

(Pl. LXXVI, figs. 1, 1*a*–*l*.)

Hyolithes excellens Billings, 1874. Geol. Sur., Canada: Pal. Foss., vol. 2, pt. 1, p. 70, Fig. 39.
See Bull. U. S. Geol. Survey, No. 30, 1886, p. 135.

This large, fine species was found in great abundance in the lowest portion of the Olenellus zone, on Manuel's Brook, Newfoundland. It also occurs near North Attleborough, Mass., as reported by Prof. N. S. Shaler.

Nat. Mus. Cat. Invert. Foss., 18320.

HYOLITHES QUADRICOSTATUS S & F.

(Pl. LXXVIII, figs. 1, 1*a*, *b*.)

Hyolithes quadricostatus Shaler & Foerste, 1888. Bull. Mus. Comp. Zool., vol. 16, pp. 31, 32, Pl. ii, Fig. 15.

"Shell straight, elongate, tapering gradually to an acute point; apical angle 17°. The external cast of the type specimens is 20^{mm} long; including an additional length represented by an internal cast of the same specimen, but extending farther from the apical extremity, it is 25^{mm} long. As the end of the cast is broken, a length of 30^{mm} may be presumed for the entire specimen. The supposed dorsal side is broad and flat or slightly concave along the center; when depressed, a low elevation may occur along the median line; in all cases, the surface retains a rather flat appearance. The lateral angles are rounded. The supposed ventral side is as usual flattened

along the median line for about half the width of the shell. The sides of this flattened surface are more or less elevated, giving it a slightly concave appearance along the median line. Immediately beyond the flattened surface on either side is a more or less distinct groove. The result is, that, in addition to the two lateral angles, there are two angles or ridges on the ventral side, giving the entire shell the quadricostate appearance indicated by the specific name. The two ventral ridges increase in distinctness as they recede from the apical extremity, and are usually more distinct, or at least less rounded, than the lateral angles. At a distance of six or seven millimeters from the apical extremity the shell is crossed by an apparently imperforate septum. The cast of this septum from the upper side had the appearance of a flattened surface with a slightly elevated border around the margin. The surface of the shell is marked by fine transverse striæ. The longitudinal ridges are less prominent on the interior cast of the shell than on the exterior.

"Taken by itself this species would appear to be very distinct from the usual forms of Hyolithes, but in reality it forms only the extreme of a series of intermediate species, which begins with specimens characterized by numerous fine longitudinal striæ, these striæ increasing in size and diminishing in number until we have such forms as *Hyolithes hexagonus* Barrande, with only four ridges in addition to the normal two lateral angles. In the specimens here described, this number is reduced to two additional costæ. The character of the variation is quite distinct from that afforded by a more acute or salient ventral median line alone.

"*Locality and position.*—Station No. 2, North Attleborough, Mass.; Cambrian; rare."

This species of the North Attleborough Olenellus zone fauna was found in the lower part of the Olenellus zone, in Newfoundland. The figure of the type specimen, described above, shows a crushed, flattened shell, quite unlike the other specimens now before me.

Nat. Mus. Cat. Invert. Foss., 18318.

HYOLITHES SIMILIS Walcott.

(Pl. LXXV, figs. 3, 3*a*–*d*.)

Hyolithes similis Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, p. 38.

Form an elongate subtriangular pyramid, gradually and regularly tapering to an acute extremity. The apical angle of the dorsal side is about 13°. Transverse section subtriangular. The ventral angle is sharp and the lateral angles rounded. Dorsal face slightly arched longitudinally, transversely nearly flat, except at the sides, where it curves slightly to meet the two planes of the ventral face, which is strongly angular at the center. Aperture oblique; the peristome is indented at the center of the ventral side and arched over the sub-

spatulate extension of the dorsal face. Operculum unknown. Shell comparatively thin.

Surface of the shell marked by tranverse or concentric striæ that arch forward on the dorsal face and slightly backward to the center on the ventral face. The ventral face is further marked by four raised lines on each side of the central angle, and between the raised lines by very fine longitudinal striæ.

The portion preserved of the largest specimen collected has a length of 43^{mm}. When entire it was about 50^{mm} in length, with a width at aperture of 13^{mm} and a depth of 7^{mm}.

In general form this shell is closely related to *H. americanus*. It differs in the strongly marked ventral surface.

Formation and locality same as *H. terranovicus*.

Nat. Mus. Cat. Invert. Foss., 18317.

HYOLITHES TERRANOVICUS Walcott.

(Pl. LXXVIII, figs. 3, 3*a–d*.)

Hyolithes terranovicus Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, pp. 37, 38.

Form an elongate subtriangular pyramid, gradually and regularly tapering to an acute extremity. The apical angle of the dorsal side is very nearly 15°. Transverse section subtriangular or semi-elliptical. Dorsal face slightly convex and curving gently from the extremity to the anterior subspatulate portion. Ventral face strongly and regularly convex transversely; the dorsal and ventral faces meet to form the rounded lateral angles of the shell. Aperture oblique, the margin extending on the dorsal side; the peristome of the ventral side is slightly curved backward. Operculum unknown. Shell thick and strong.

Surface of the shell transversely or concentrically striated. On the dorsal surface the striæ are faintly defined, and on the ventral surface strongly marked, and also cancellated by raised lines with finer striæ between.

The largest specimen collected has a width of 16^{mm} at the aperture, and a length of about 55^{mm} is indicated, the portion preserved being 48^{mm} in length.

I do not know of any closely allied species, although the surface markings are like those of *Hyolithes nobilis* Barrande.[1]

The presence of a septum near the extremity of the shell is shown very distinctly in one specimen, where the point is broken off.

Formation and locality.—Lower Cambrian. This species was found in irregular masses of limestone resting on and among the bowlders of gneiss forming the base of the Olenellus zone on Manuel's Brook, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18319.

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[1] Syst. Sil. Bohême, vol. 3, 1867, Pl. 13, Figs. 22–26.

HYOLITHELLUS Billings.

HYOLITHELLUS MICANS Billings.

(Pl. LXXIX, figs. 1, 1*a–e*.)

See Bull U. S. Geol. Survey, No. 30, 1886, p. 142.

This is a widely distributed species. It is reported from Newfoundland, eastern Massachussetts, and eastern New York, the St. Lawrence Valley, and, doubtfully, from Nevada.

Nat. Mus. Cat. Invert. Foss., 15381, 15382.

HYOLITHELLUS MICANS var. RUGOSA Walcott.

(Pl. LXXIX, fig. 2.)

Hyolithellus micans var. *rugosa* Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, p. 191, pl. i, fig. 10.

This name was proposed for a variety of *Hyolithellus micans* that has well marked concentric ridges with longitudinal striæ between them. The substance of the shell appears to be similar to that of *H. micans*. (See Bull. 30, U. S. Geol. Survey, p. 142.)

Formation and localities.—Lower Cambrian; limestones interbedded in the shaly slates on the roadside just west of Low Hampton crossing on the Poultney River; lowest fossiliferous horizon on D. W. Reid's farm and on hill back of Reid's farm-house, one and one-half miles west of North Greenwich; two miles south of North Granville; and in the north part of Easton, about one mile south of the village of Greenwich, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17444.

COLEOLOIDES Walcott.

Coleoloides Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, p. 37.

Shell slender, elongate, cylindrical, straight or slightly curved, apparently thin.

Surface marked by very fine, slightly oblique or spiral longitudinal striæ, in the only species known.

In form this shell is like that of *Hyolithellus micans*, but the surface markings are unlike those of either *Hyolithellus* Billings or *Coleolus* Hall.

COLEOLOIDES TYPICALIS Walcott.

(Pl. LXXIX, figs. 6, 6*a*.)

Coleoloides typicalis Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, p. 37.

Straight, elongate, cylindrical shells, that taper so gradually that the diminution in size is apparent only in long pieces of the tube, and then only by the closest examination. Shell apparently very thin.

Surface marked by very fine, slightly oblique, longitudinal striæ, that are a little irregular in their course, as shown by a strong magnifier. The striæ make one revolution around the tube in a length of sixteen diameters of the tube.

The longest specimen found has a length of 23^{mm} and is about one-half a millimeter in diameter. It is broken off at each extremity.

I do not know of any related species.

Formation and Locality.—Same as *Hyolithes terranovicus.*

Nat. Mus. Cat. Invert. Foss., 18326.

SALTERELLA Billings.

SALTERELLA PULCHELLA Billings.

(Pl. LXXIX, figs. 5, 5*a-e*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 144.

Nat. Mus. Cat. Invert. Foss., 15375.

SALTERELLA RUGOSA Billings.

(Pl. LXXIX, fig. 4.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 145.

Nat. Mus. Cat. Invert. Foss., 14901.

SALTERELLA CURVATUS S. & F.

(Pl. LXXIX, figs. 3, 3*a*.)

See Bull. Comp. Zool., Harvard College, vol. 16, 1888, p. 34.

Type in collection of N. S. Shaler.

CRUSTACEA.

ISOXYS, n. gen.

Carapace large; dorsal margin slightly curved; dorsal angles produced into sharp points; anterior and posterior ends alate, subequal in outline, and merging into the rounded ventral margin without forming an angle; marginal rim narrow; valves equal; surface apparently smooth.

Type *Isoxys chilhoweana*, n. sp. This species varies so decidedly from the usual type of Leperditia and allied genera that there is little comparison to be drawn between them. The most nearly related form known to me is *Leperditia ? argenta*[1] of the Middle Cambrian zone of Utah. The latter has the characteristic outline of Leperditia, but that of Isoxys is more like that of a brachiopod shell of the genus Leptæna.

[1] Bull. U. S. Geological Survey, No. 30, 1886, p. 146, pl. 8, fig. 5.

ISOXYS CHILHOWEANA, n. sp.

(Pl. LXXX, figs. 10, 10*a*.)

The generic description includes the principal characters of the species. The specimens are nearly all flattened in the rock and indicate by the wrinkles that the shell was thin and readily compressed. The narrow furrow within the wire-like ventral rim retains its form, and one specimen shows the two valves with a slight convexity in each.

Dimensions.—The largest specimen has a length, at the dorsal margin, of 40^{mm}, with a depth of 15^{mm}.

The associated species are Hyolithes, like *H. americanus*, *Olenellus sp.* and numerous finely preserved annelid trails. The subjacent sandstones are full of slender Scolithus borings.

Formation and localities.—Lower Cambrian; in shale resting on Chilhowee quartzite, Little River Gap, and near Montvale Springs, Chilhowee Mountain, Tennessee.

Nat. Mus. Cat. Invert. Foss., 18444.

LEPERDITIA Roualt.

LEPERDITIA (I) DERMATOIDES Walcott.

(Pl. LXXX, figs. 1, 1*a*.)

Leperditia (I) dermatoides Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, pp. 192, 193, Pl. i, Figs. 13, 13*a*.

Outline of the valves elongate, suboval, with the extremities of the hinge line rounded, subangular; moderately convex, sloping more rapidly to the ventral than the dorsal margin; in many specimens, however, it is difficult to determine the ventral from the dorsal margin, owing to their almost equal curvature and similar rounding of the ends; the hinge line is arched and but slightly marked. It is difficult to determine the anterior and posterior ends of the valves in many of the specimens, but in others the narrower end is considered as the anterior, and a small, round depression on the inner side of the valve places the muscular scar well toward the posterior end. The scar is barely visible on the outer surface.

The test is finely punctate, and so thin that it wrinkled in some instances like a membrane or skin.

Length of undistorted specimen, 6^{mm}; greatest height, 3.5^{mm}.

The strongly punctate surface is so unlike that of all the species referred to Leperditia that it may be that this species should be referred to a distinct genus.

In its punctate surface and general form it is unlike any other species known to me.

Formation and localities.—Lower Cambrian; limestones interbed-

ded in the shaly slate, north part of Easton, about one mile south of the village of Greenwich; on the west side of D. W. Reid's farm and on the summit of the hill northwest of his farm-house, about one and one-half miles west of North Greenwich; about three miles northeast and one-half mile east of North Greenwich; near Rock Hill school-house (No. 8), east of North Greenwich; and one mile south-southeast of Battenville, in the town of Jackson, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17448.

ARISTOZOE Barrande.

ARISTOZOE ROTUNDATA Walcott.

(Pl. LXXX, fig. 3.)

Aristozoe rotundata Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, pp. 193, 194, Pl. i, Fig. 9.

General outline of the valves subrotund, with the exception of the nearly straight hinge line; anterior end slightly narrower than the posterior; general surface rather strongly convex, marked all around, except along the hinge line, by a strong marginal groove within a rounded marginal rim; a single elongate protuberance extends from the main body of the shell upward, just within the anterior marginal groove and the hinge line, where it is most prominent, and separated from the main body of the valve by a broad sulcus extending from the hinge line down on the valve over two-fifths the distance to the ventral margin.

The shell is thin and apparently very finely granulose.

A comparison with the types of the genus Aristozoe shows this species to be congeneric with them and specifically distinct from any described species of the genus. *Aristozoe bisulcata*[1] has a similar outline, but the tubercle is unlike that of *A. rotundata*, and it is differently situated on the valves. It is distinguished from *A. troyensis* by its form and also the elongate tubercle or ridge.

The discovery of this species and the generic identification of *A. troyensis* adds another Silurian genus to the Cambrian fauna, and extends its range from the true Silurian down to the Middle Cambrian. As yet I do not know of the presence of the genus in the Lower Silurian (Ordovician) rocks.

Formation and locality.—Lower Cambrian; limestones interbedded in the shaly slates on M. C. Tefft's farm, about two miles southeast of North Greenwich, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17446.

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[1] Barrande, Syst. Sil. Bohême., vol. i, 1872, Supplement, p. 477.

ARISTOZOE TROYENSIS Ford (sp.)

(Pl. LXXX, figs. 2, 2*a*.)

Leperditia troyensis Ford, 1873. Am. Jour. Sci., 3d series, vol. 6, p. 138; Walcott, 1886, Bull. 30, U. S. Geol. Survey, p. 146.

Aristozoe troyensis Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, p. 193, Pl. i, fig. 8.

The discovery of another specimen of this species enables me to refer it to the genus Aristozoe of Barrande. The thin test, grooved and reflected ventral margin, anterior tubercle and general form, all serve to connect it with that genus. In Bull. 30, U. S. Geol. Survey, a figure is given of the right valve, and I am now able to figure the left valve. The tubercle on the anterior end is elevated and directed forward.

A third species of Aristozoe occurs in the upper portion of the Olenellus zone, in Washington County, N. Y. Owing to the imperfection of the specimens it is not practicable to give a specific description.

Formation and localities.—Lower Cambrian; limestones interbedded in the shaly slates, on the ridge east of the city of Troy, N. Y.; also at the lowest fossiliferous horizon, on the west side of D. W. Reid's farm, about one-half mile west of North Greenwich, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17447.

NOTHOZOE Barrande.

NOTHOZOE ? VERMONTANA Whitfield.

(Pl. LXXX, figs. 4, 4*a*, *b*.)

See Bull. Am. Mus. Nat. Hist., vol. 1, 1884, p. 144, Pl. 14, Figs. 14, 15.

The specimens described and illustrated by Mr. Whitfield are more or less distorted by compression. A number of specimens were found in a bowlder on Sunset Hill, near Lake Dunmore, that appear to have retained their original outline and convexity. There is considerable variation in outline, as shown by the specimens figured on Plate LXXX. In many instances we appear to have an undoubted lamellibranchiate shell before us, but in other cases the resemblance to Nothozoe or some related bivalve crustacean is so marked that the weight of evidence favors the provisional reference to Nothozoe.

I found this species in situ in the quartzite east of Bennington, Vt. The associated fossils are *Olenellus* sp.? and *Hyolithes impar.*[1]

[1] Identified from more imperfect material as *Hyolithes communis* (Am. Jour. Sci., 3d series, vol. 35, 1888, p. 234), and by Mr. Whitfield as *H. gibbosus*, of the Potsdam sandstone. Bull. Am. Mus. Nat. Hist., vol. 1, 1884, p. 144.

PROTOCARIS Walcott.

PROTOCARIS MARSHI Walcott.

(Pl. LXXXI, fig. 6.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 148

Nat. Mus. Cat. Invert. Foss., 15400.

TRILOBITA

AGNOSTUS Brongniart.

AGNOSTUS NOBILIS Ford.

(Pl. LXXX, fig. 8.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 150.

The generic reference of this species is doubtful, as it may be a Microdiscus.

Type reported lost by S. W. Ford.

AGNOSTUS DESIDERATUS Walcott.

(Pl. LXXX, fig. 5.)

Agnostus desideratus Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, pp. 39, 40.

Cephalic shield about as broad as long, broadly rounded in front, sides curving in very slightly towards the posterior margin; posterior margin sloping obliquely inward from the postero-lateral angles to the median lobe. A narrow raised rim extends all around the margins except across the base of the glabellar or median lobe. The space between the rim and the glabella is slightly convex. Glabella less than two-thirds the length of the head, narrow, subcylindrical and with a small tubercle on the posterior third. Surface smooth. A pygidium, associated with the head on the same piece of rock, has a prominent median lobe, bordered by a narrow, convex space between it and the marginal rim. The median lobe does not show any indication of lateral or transverse furrow. An elongate median tubercle is the only ornament.

This type of Agnostus occurs in the Middle Cambrian zone of the Atlantic Basin as *A. parvifrons* Linnarsson, and *A. brevifrons* Linnarsson of Sweden, and *A. tessella* Matthew and *A. umbo* Matthew of New Brunswick.

Formation and locality.—In the upper portion of the Lower Cambrian rocks, a short distance northeast of Salem, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 18327.

AGNOSTUS sp.?

(Pl. LXXX, fig. 6, 6a.)

This species is represented by two imperfect heads of the type of *Agnostus fallax* Linnarsson, of the Middle Cambrian of Sweden, or *A. acadicus* Hartt, of New Brunswick. It is found at the same locality with *A. desideratus*, and also two miles south-southeast of Granville, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 18328.

MICRODISCUS (Emmons) Walcott.

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 152.

MICRODISCUS BELLIMARGINATUS S. & F.

(Pl. LXXXI, figs, 2, 2a, b.)

Microdiscus bellimarginatus Shaler & Foerste, 1888. Bull. Mus. Comp., p. 35, 36, Pl. ii, Fig. 19.

"Head semicircular, 4.3^{mm} long and 5^{mm} broad. The glabella is oblong, strongly convex, slightly narrowed in front. It is well defined by a deep, distinct groove, which continues around the sides and anterior part of the glabella; it is not connected at the front with the groove which lies along the border of the head and within the rim. The marginal groove is deep, broad in front, gradually growing narrower toward either side; it gives a high relief to the rim. The marginal rim has very nearly the same breadth throughout its length; it is beset with small tubercles, usually sixteen or eighteen in number, which lie near the interior margin of the ridge. The tubercles directly in front of the glabella are often indistinct or obsolete. The occipital furrow behind the glabella is low and not very distinct. It serves chiefly to bring into greater prominence a tubercle on the middle of the occipital ring. This tubercle is directed backward, varies in size, and is often low, and again may become a large sharp-pointed tubercle in the form of an incipient nuchal spine. The extension of the occipital furrow along the posterior part of the cheeks is very deep and marked, giving high relief to the cheeks. The posterior rim is very narrow, but sharp and distinct, and the postero-lateral extremities of the head have very small acute terminations, without which they would appear somewhat rounded. The cheeks are connected in front by a narrow, sharply rounded ridge, which lies a short distance from the glabella, along its anterior border.

"The pygidium is of an oval form, and is about 5^{mm} broad and 4.3^{mm} long. The middle lobe is strongly divided from the side lobes by grooves. It is very convex, and is also curved antero-posteriorly, giving the pygidium a strongly convex outline from front to rear as

well as from side to side. It is divided into nine or ten segments; along the median line is a series of tubercles, very distinct on the anterior segments, diminishing in size near the posterior extremity. The sides show no traces of segmentation. They are connected posteriorly by a narrow ridge similar to that connecting the cheeks The rim is sharp and distinct, being well defined by a furrow which lies between it and the side lobes. The specimens are usually of the size above noted, but one almost entire pygidium found at locality No. 2 must, when perfect, have been at least 8^{mm} long.

"*Locality and position.*—Stations Nos. 2 and 3, North Attleborough, Mass.; Cambrian; thirty specimens."

This species is very closely related to *Microdiscus meeki* Ford. I found *M. bellimarginatus* associated with *Olenellus* (*H.*) *bröggeri* 300 meters north of Manuel's Brook, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18329.

MICRODISCUS CONNEXUS Walcott.

(Pl. LXXX. figs. 9, 9 *a*, *b*.)

Microdiscus connexus Walcott, 1887. Am. Jour. Sci., 3d series. vol. 34, p. 194, Pl. i, Figs. 4, 4*b*.

Head semicircular, convex; bordered by a well defined rim that is crenulated across the front and narrowed posteriorly toward the glabella, where it terminates; cheeks most prominent at the postero-lateral portion, from whence they slope to the deep dorsal furrow about the glabella; the glabella and its backward spinose extension form, together, a fusiform median lobe, as there is no occipital furrow or ring and the glabella and the spine are continuous. The glabella approaches the frontal margin more closely in some specimens than in others. The surface of both the head and pygidium appears smooth under a strong magnifying glass.

A glance at the head of this species recalls *Microdiscus punctatus*, *M. punctatus* var. *pulchellus*, and *M. dawsoni* of the Lower Cambrian. It has the frontal rim and form of *M. dawsoni*, but it is a smooth, not granulose species; and the associated pygidium is unlike that of *M. dawsoni*. To *M. punctatus* it is related by its general form, but differs in the more coarsely crenulated margin, the form of the cheeks and its smooth surface, also in the characters of the associated pygidium. The presence of this type of the genus Microdiscus in association with well known Lower Cambrian fossils is another link between the Middle Cambrian fauna of New Brunswick and the Lower Cambrian fauna. It is the first instance known to me of the probable occurrence of a species with the long nuchal spine below the Paradoxides horizon in America.

This species has recently been found a little northeast of Salem, Washington County, N. Y., also near Volatie Creek, in the southern

part of Rensselaer County, N. Y., and in a limestone bowlder in the Sillery conglomerate on the south shore of the Island of Orleans.

Formation and localities.—Lower Cambrian; limestones interbedded in the shaly slates, on the roadside just west of Low Hampton crossing of the Poultney River; one mile west of North Hebron: and two miles south of North Granville, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17449.

MICRODISCUS MEEKI Ford.

(Pl. LXXXI, fig. 3.)

See Bull. U. S. Geol. Survey, No. 30, p. 155.

Type in collection of S. W. Ford.

MICRODISCUS PARKERI Walcott.

(Pl. LXXX, figs. 7, 7*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 157.

Nat. Mus. Cat, Invert. Foss., 15396.

MICRODISCUS LOBATUS Hall (sp.)

(Pl. LXXXI, figs. 4, 4*a*, *b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 156.

The head, represented by Fig. 1a, Pl. 16, of Bulletin 30, was referred to this species. It is probably a very young specimen of *Microdiscus speciosus*. This species also occurs near North Attleborough, Mass.[1]

Nat. Mus. Cat. Invert. Foss., 15394.

MICRODISCUS SPECIOSUS Ford.

(Pl. LXXXI, figs. 5, 5*a*–*c*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 154.

Since Bulletin 30 was written, this species has been found in many localities in Washington County, N. Y., also near North Attleborough, Mass.

Nat. Mus. Cat. Invert. Foss., 15397.

MICRODISCUS HELENA Walcott.

(Pl. LXXXI. figs. 1, 1*a*.)

Microdiscus helena Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, p. 40.

Head convex, bordered all around by a continuous marginal rim that is narrow at the back and sides and broad in front. Three small

[1] Bull. Mus. Comp. Zool., Harvard College, vol. 16, 1888, p. 36.

nodes occur on the anterior lateral portion of the rim, the center one being on the line of the frontal margin of the glabella. Glabella prominent, cylindro-conical, tumid posteriorly; two furrows cross the middle third so as to separate a narrow central lobe, an anterior lobe nearly twice as long as the central lobe, and a tumid posterior lobe that equals the anterior lobe in length. Dorsal furrows strong; the furrow within the margin is broad and well defined all around except at the occipital furrow crossing the glabella, where it is very narrow; it curves backward inside the very narrow rim at this point. Cheeks tumid, and overhanging the outer marginal groove.

The pygidia associated with the heads are strongly convex. The median lobe, at the center, is a little more than one-third of the entire width of the pygidium; it is crossed by five transverse furrows that divide it into five segments and a short terminal segment just inside the strongly defined marginal groove; dorsal furrows strong; marginal rim narrow; lateral lobes slightly convex, smooth.

The head of this species is related to that of *M. meeki* and *M. lobatus*. The tumid posterior lobe of the glabella serves to distinguish it from them and also all described species. The associated pygidium differs from that of *M. bella-marginatus* in being more convex and in having five instead of nine segments in the median lobe.

Formation and locality.—Lower Cambrian.; in a decomposed limestone 600 meters west of Manuel's Brook, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18361.

MICRODISCUS, sp. undet.

This species is indicated by a number of pygidia that occur in the Olenellus-bearing limestone of Brigus and Topsail Heads, Conception Bay, Newfoundland. It may be that they should be referred to *M. meeki*, but at present I do not think this is warranted by the material.

OLENELLUS Hall.

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 162.

Thinking that Olenellus succeeded the genus Paradoxides in time, and accepting the interpretation given by Mr. Ford to the embryonic characters of *O.* (*M.*) *asaphoides*, I argued in favor of the descent of Olenellus from Paradoxides. It was an error, as the finding of Olenellus beneath Paradoxides abundantly proves. The discovery of more perfect specimens of *O.* (*M.*) *asaphoides* shows that what I had identified as the facial suture is a raised line in the cast of the interior of the shell that fills a depressed line occupying the position of the suture. I have since found this raised line in many specimens,

but in none is there a true suture cutting through the shell, as in Paradoxides and most other genera of trilobites.

There is now brought together for the first time the means of a direct comparison of the various species that have been referred to this genus. The type of the genus, *Olenellus thompsoni*, (Pl. LXXXII, fig. 1) and the western American species, *O gilberti* (Pl. LXXXIV, fig. 1), are so manifestly congeneric that there can be no question raised as to the validity of placing them in the same genus. The form originally described as *Olenellus vermontana* (Pl. LXXXVII, fig. 1*a*) I have referred to the genus Mesonacis on account of the extraordinary extension of the the thorax, the large dorsal spine, and the difference in the character of the pygidium as compared with that of *O. thompsoni*. Brögger, Holm, and Schmidt, however, were not inclined to admit a generic distinction, and I now think it quite as well to consider it as a sub-genus of Olenellus.

On account of the difference in the pygidium and the absence of the prolonged third segment in *Olenellus* (*H.*) *kjerulfi* (Pl. XCIII, fig. 2,) Matthew has proposed the genus Holmia to include it.[1] *Olenellus* (*M.*) *mickwitzia* (Pl. XCIII, fig. 1,) differs from *O. kjerulfi* in having a large spine upon the eighth segment. In speaking of this species Prof. Jules Marcou says: "In reality this trilobite possesses generic differences and constitutes a new sub-genus, closely allied to Paradoxides, and in which may be included *Mesonacis vermontana* and *Olenoides typicalis*, the latter being an extreme degenerate form of the type. I propose to call it *Schmidtia*, in honor of Prof. F. Schmidt.[2] This suggestion of Professor Marcou's shows an entire absence of knowledge of what has been done with the sėveral species he refers to. He disregards the fact that Mesonacis was proposed as a distinct genus from Olenellus, and that *Olenoides typicalis* is the type of the genus Zacanthoides.[3] If his correlations were correct the *Olenellus mickwitzia* would be referred either to Mesonacis or Zacanthoides. *Zacanthoides typicalis* has not even a family, much less a generic relation to it; and Mesonacis has already been used to include *O. mickwitzia* by Schmidt.

We now have proposed for this group of species the genera Olenellus, Mesonacis, Holmia, and Schmidtia. There are other forms described in this review that, according to the principles of generic determination advanced by Matthew and Marcou, should receive separate generic recognition. The *Olenellus* (*H.*) *bröggeri* (Pl. XCI) varies from described species in having a great prolongation of the occipital segment and a peculiar narrowing of the glabella. In *Olenellus* (*M.*) *asaphoides* (Pl. LXXXIX, fig. 1,) we find five extended spines upon the five posterior thoracic segments. We have here again

[1] Trans. Roy. Soc. Canada, vol. 7, sec. 4, 1890, p. 160.

[2] American Geologist, vol. 5, 1890, p. 363.

[3] Am. Jour. Sci., 3d ser., vol. 36, 1888, p. 165.

another generic (?) character, as the spines are on different segments from those in *O. vermontana* and *O. mickwitzia*. There still remains the species *O. iddingsi* (Pl. LXXXIV, fig. 2). From the character of the side spines and the glabella this is quite as much entitled to generic recognition as some of the forms that we have been considering.

There are now nine recognized species of Olenellus, and if the grounds of generic differentiation already noted are adopted they would be referred to seven genera. To me this would be an incorrect interpretation of the characters presented by the various species. I think, however, it might be convenient to divide them into sections by subgenera in the following manner:

Olenellus: *O. thompsoni, O. gilberti, O. iddingsi ??*

Mesonacis: *O. (M.) vermontana, O. (M.) mickwitzia,* and *O. (M.) asaphoides.*

Holmia: *O. (H.) kjerulfi, O. (H.) bröggeri, O. (H.) calevi.*

Little attention has been given, since the appearance of Holm's memoir, to the fact of the absence of true facial sutures in the genus Olenellus. In the desire to correlate this genus with Paradoxides this most essential character of classification appears to have been entirely ignored. It is true that Holm has shown the presence of the suture along the doublure of *O. kjerulfi*, but in none of the species is there a facial suture such as characterizes the family Paradoxidiæ. On this account I think it would be well to separate the Olenellus entirely from the family, and as it is not advisable to use the name Olenellidiæ, on account of its similarity to Olenidiæ, I propose that the various genera and subgenera be grouped under the name Mesonacidiæ, taking the *Olenellus (Mesonacis) vermontana* as typical of the family, in connection with its associated species *O. thompsoni.*

The distinguishing characteristic of the family, when compared with the Paradoxidiæ, is the absence of facial sutures. In this respect it resembles the Trinuclidiæ in having the sutures submarginal or none, and differs decidedly from the Paradoxidiæ, which includes Paradoxides, Anopolenus, etc.

The development of the third segment into prolonged pleural lobes is a character that appears in the young of *Olenellus (M.) asaphoides*, but not in the adult. A similar character is prominent in *Paradoxides bohemica* and *P. spinosus* in the development of the second segment.

OLENELLUS THOMPSONI Hall.

(Pl. LXXXII. figs. 1, 1*a*; Pl. LXXXIII. figs. 1, 1*a*, *b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 167.
Nat. Mus. Cat. Invert. Foss., 15418, 15419.

OLENELLUS GILBERTI Meek.

(Pl. LXXXIV, figs. 1, 1*a–g;* Pl. LXXXV, figs. 1, 1*a–g;* Pl. LXXXVI, figs. 1, 1*a–m*, 4.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 170.
Nat. Mus. Cat. Invert. Foss., 15411, 15412, 15416.

OLENELLUS IDDINGSI Walcott.

(Pl. LXXXIV, fig. 2.)

Nat. Mus. Cat. Invert. Foss., 14510.

OLENELLUS WALCOTTI S. & F.

(Pl. LXXXVIII, fig. 2.)

Paradoxides walcotti Shaler & Foerste, 1888. Bull. Mus. Comp. Zool., Harvard College, vol. 16, pp. 36–37, Pl. ii, Fig. 12.

"A single specimen was found showing the under side of the integument which covered the head 2.8^{mm} long and 3.8^{mm} broad. The cheeks are in position, and the facial suture is barely indicated by a faint line running from the anterior extremity of the palpebral lobe forward, bending at first a little outward, then more rapidly inward near the margin, which it cuts; posterior to the palpebral lobe it almost immediately cuts the margin in a slight outward curve. The outline of the head forms a curve, which would be semicircular were it not for its disproportionate breadth. There are faint indications of a spine at the postero-lateral extremities. The glabella is broad in front, the posterior half, with incurved sides, narrowing to half its anterior width. The occipital furrow is distinct and the occipital ring has a distinct tubercle at the middle. The glabella is marked by three pairs of shallow furrows, with perhaps a fourth scarcely discernible pair. The second and third pairs are not seen to meet across the median line; but owing to the position of two very low and rather indistinct tubercles, one anterior and one posterior to the first or posterior pair of furrows along the median line, these furrows seem to meet in a curve bending slightly backward along the middle of the glabella. The palpebral lobes are large and prominent, beginning a little anterior to the third pair of furrows and curving around to within a very short distance of the extension of the occipital furrow across the cheeks. The curve along the anterior border of the head is regular. A shallow groove runs within a short distance of the anterior border, gradually becoming deeper and broader and receding more from the border on the sides of the head, so that the rim here becomes broader. A faintly discernible, shallow pit near the anterior extremity of the glabella may in this case be only accidental.

"*Paradoxides tenellus* Billings is in size like this species, but otherwise very distinct. It is interesting to find a Paradoxides in the Olenellus Cambrian, since its occurrence there diminishes the importance of the Paradoxides Cambrian as a Paradoxides division.

"*Locality and position.*—Station No. 2, North Attleborough, Mass.; Cambrian; one specimen."

This species is described under the genus Paradoxides, but, on comparing the type specimen with specimens of the head of *Olenellus asaphoides*, of similar size and condition of preservation, I can find no characters of generic difference between them. The specific characters are very close to those of *O. asaphoides*, and the specific name is only retained tentatively until more material can be collected from the original locality. The facial suture, shown on the original figure, represents the depressed line that is seen in the interior of the shell of *Olenellus gilberti*, etc. It is not a true suture.

This species is found with six species that occur in association with *Olenellus* (*M.*) *asaphoides*, in Rensselaer and Washington Counties, N. Y., viz.: *Fordilla troyensis, Stenotheca rugosa, Platyceras primœvum, Hyolithes communis* var. *emmonsi, H. americanus* and *Hyolithellus micans.*

Formation and locality.—Lower Cambrian, near North Attleborough, Mass.

Subgenus MESONACIS Walcott.

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 158.

With the discovery of entire specimens of *Olenellus asaphoides*, and *O. mickwitzia*, it appears that *Mesonacis vermontana* is to be grouped with them, and all referred to Mesonacis as a subgenus, on account of the peculiar pygidium of *Olenellus thompsoni*, the type of the genus, as compared with that of *O.* (*Mesonacis*) *vermontana*, the type of the subgenus *O.* (*M.*) *vermontana*.

OLENELLUS (MESONACIS) VERMONTANA Hall.

(Pl. LXXXVII, figs. 1, 1*a*, *b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 158.

Nat. Mus. Cat. Invert. Foss., 15399.

OLENELLUS (MESONACIS) ASAPHOIDES Emmons (sp.)

(Pl. LXXXVI, figs. 3, 3*a*-*b*; Pl. LXXXVIII, figs. 1, 1*a*–*g*; Pl. LXXXIX, figs. 1, 1*a*; Pl. XC, figs. 1, 1*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 168.

The discovery of entire specimens of this species shows that it has 18 segments in the thorax, and a small transverse pygidium of the

Parodoxides type. On each of the five short posterior segments of the thorax there is a long, slender spine that projects back over the pygidium. The entire specimens were found at the original locality of the species, near the old Reynolds Inn buildings, one mile west of North Greenwich, Washington County, N. Y. Bald Mountain is given as the type locality by Emmons, but Dr. Fitch found the specimens used by Emmons a mile to the north, near Reynolds's Inn.

Nat. Mus. Cat. Invert. Foss., 18350.

OLENELLUS (HOLMIA) BRÖGGERI Walcott.

(Pl. XCI, fig. 1; Pl. XCII, figs. 1, 1*a-h*.)

Olenellus bröggeri Walcott, 1888. Name proposed at exhibition of specimens at the International Geological Congress, London. Name used in "Nature," vol. 38, p. 551, 1888.

General form ovate, the length and breadth nearly as 3 to 2, in comparing the length of the entire body with the width of the head. Head broad, semicircular in outline and moderately convex, when preserved in limestone, but very much compressed in the shales. Margin rather broad, but varying in width one-half in different individuals; it is slightly rounded and separated from the frontal limb and cheeks by a shallow groove and narrow, low ridge; posteriorly, it terminates in a comparatively short, strong spine. The posterior margin of the head, between the glabella and postero-lateral spine, is broken just within the latter by a deep notch and a short spine that corresponds to the "interocular" spine (Ford) of *Olenellus* (*M.*) *asaphoides* and the spine at the pleural angles of the posterior margin of *O.* (*H.*) *kjerulfi*; a low ridge extends from back of the eye, next to the glabella, out to the spine, much as in *O.* (*H.*) *kjerulfi*; the spine varies in size and direction from the young individual, where it is directed backward (Pl. XCII, fig. 1*h*), to the large adult, in which it extends obliquely outward (Fig. 1*b*). The under side of the margin forms a broad "doublure," as shown in Fig. 1*e*. It is slightly arched downward, and narrows towards the postero-lateral angles of the head. A slight curved indentation occurs at the point of attachment of the hypostoma. It is a very common occurrence to find the "doublure" on the reflected under margin lying free from the other parts of the head (on the shale) and with the hypostoma attached. This fact leads to the conclusion that a suture passes around near the frontal margin, in the same manner as Holm describes it in *O.* (*H.*) *kjerulfi*.[1]

Glabella clavate, narrow at the base, reaching its greatest width just back of the anterior termination of the eye-lobes; it narrows rapidly towards the rather sharply rounded frontal margin. Three pairs of glabellar furrows occur as shallow depressions, the anterior one being opposite the point where the eye-lobe merges into the

[1] Aftryck. vr. Geol. Fören. i Stockholm. Förhandl., Bd. ix, Haft 7, p. 116' 887.

frontal lobe of the glabella; the furrows on the opposite sides extend in towards the center, but do not unite. Occipital furrow shallow and extending back from each side towards the center. Occipital ring narrow at the sides and increasing rapidly in width to the center, where it supports a long, strong spine that curves back over the thorax. None of the specimens show the entire spine, but I think it extends back fully one-half the length of the thorax. Eye-lobes crescentiform, narrow, elongate, arching from the base of the anterior lobe of the glabella, into which they merge, back to a line with the occipital furrow and some distance from the glabella; visual surface unknown. The area between the glabella and eye-lobe is slightly depressed, a narrow, shallow furrow extending along the inner edge to the eye-lobe. The frontal limb and cheeks slope gently to the ridge within the outer margin. No traces of facial sutures observed, although in some of the casts of the inner side of the shell a depressed line in the shell is indicated by a raised line on the cast. This line follows the direction I should theoretically give to the suture. Hypostoma moderately convex, broad in front and narrowing towards the posterior margin.[1] One specimen is 18^{mm} across the greatest width and 12^{mm} across the posterior end. The anterior margin shows a rounded smooth edge that fits into the slight curved recess of the "doublure" of the head except laterally, where it extends out to meet the side margin of the anterior wings to form a blunt point; back of the anterior wings, the margin is raised to form an elevated rim and then curves under; the rim extends around to and across the posterior margin, becoming most prominent at the postero-lateral angles; the marginal rim is separated from the body by a sulcus that disappears on the anterior wings; the posterior groove, in front of the marginal sulcus, is well defined and arches backward from side to side, and, although very shallow at the center, it leaves a prominent ridge on each side between it and the posterior marginal sulcus; the anterior grooves are short and present scarcely more than pits just back of the main body of the hypostoma. This hypostoma differs from that of *O.* (*H.*) *kjerulfi* and *O.* (*M.*) *asaphoides* in being narrower anteriorly, more elongate, and with a smooth instead of a spinose posterior margin.

Thorax with 18 segments.[2] Axial lobe convex; the center of each segment bears a short, strong, curved spine, the base of which reaches longitudinally across the segment. Pleural lobes flattened about

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[1] The front margin is the point of attachment to the head, and the posterior margin that next to the mouth of the animal and facing the posterior margin of the head.

[2] A note, made in the field, records eighteen segments in the only entire specimen found. Owing to the fragile, decomposed rock the pygidium and five segments of this specimen were ground to a fine powder in transporting the large slab containing it over the rough roads to St. John.

three-fifths the distance from the axial lobe to the outer edge and then gently curving to the ends of the remaining falcate portion of the pleuræ. The narrow, median pleural grooves extend outward to the beginning of the curvature of the broad, falcate extremity of the pleura.

Pygidium small, transverse, almost quadrangular in outline. None of the examples show the details of structure with sufficient clearness to describe them.

The surface of the head and thoracic segments is ornamented with the peculiar, inosculating, fine, raised fretwork that, as far as known, is confined to the genus Olenellus.

Dimensions.—*O.* (*H.*) *bröggeri* and *O. thompsoni* are the two largest species of the genus yet described. Fragments of *O.* (*H.*) *bröggeri* now before me indicate a length of 24^{cm}. One head has a length of 8^{cm}. A bed of greenish argillaceous shale, six inches in thickness, is almost entirely formed of fragments of large specimens.

The associated fauna includes some well known Lower Cambrian species and others not heretofore described. As known now it embraces 14 genera, 23 species, and 6 varieties.

Formation and localities.—Lower Cambrian; the best specimens were secured in a reddish brown argillaceous shale in a railroad cut, about one mile west of Manuel's Brook bridge, on Conception Bay, Newfoundland. It was also found in the limestone beneath Topsail Head and on Brigus Head, on the same bay; at the base of the Manuel's Brook section, where it ranges through eighty feet of strata, and in the decomposed limestone, four hundred yards west of the brook, in a railroad cut. Stratigraphically its position is three hundred feet beneath the Paradoxides zone, in the Manuel's Brook section.

Nat. Mus. Cat. Invert. Foss., 18331.

Comparison.—The great occipital spine, small "pleural" spine of the head, broad falcate extension of the pleuræ, and short transverse pygidium distinguish *O.* (*H.*) *bröggeri* from *O.* (*H.*) *kjerulfi* and *O.* (*M.*) *mickwitzia* of Europe. With the exception of the form of the pleuræ, the same characters separate it from *O.* (*M.*) *asaphoides*, *O. thompsoni*, *O.* (*M.*) *vermontana* and *O. gilberti*. The head of *O. ? iddingsi* is quite distinct.

The species of Olenellus found in Shropshire, England, and named *O. callavei*, by Prof. Charles Lapworth, is very closely allied to, if not identical with, *O.* (*H.*) *bröggeri*. In notes on this species received from Professor Lapworth, he says:

It is most intimately allied to *Olenellus kjerulfi* and *Olenellus bröggeri*.

From *O. kjerulfi* it is distinguished by—

(1) Its size, being four or five times as large.

(2) The contraction of glabella towards the front.

(3) The more rounded and broader form of the free portions of the pleuræ.

(4) The excessive development of the meso-occipital spine.
(5) The relative position of the latero-occipital processes.
To *Olenellus bröggeri* it is far more closely allied; differing only in—
(1) The smaller size and more backward position of the eyes.
(2) The shorter meso-occipital spine.
(3) The stronger latero-occipital processes.
(4) The much longer and broader spines.
The three forms, *O. kjerulfi*, *O. bröggeri*, and *O. callavei* form a special group, lying between Olenoides and Mesonacis, wanting the meso-dorsal spine of both and having instead a strongly developed meso-occipital spine. They might form a new subgenus which could be called *Cephalacanthus*.

The letter containing the preceding was received in June, 1890, but the subgeneric name will have to give way to *Holmia*, suggested by Matthew and published in June, 1890.

OLENOIDES Meek.

See Am. Jour. Sci., 3d series, vol. 36, 1888, p. 165.

OLENOIDES FORDI Walcott

(Pl. XCIV, figs. 3, 3*a*–*c*.)

Olenoides fordi Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, pp. 195–196, Pl. i, figs. 5, 5*b*.

Head rather strongly convex, frontal margin rounded, moderately elevated, and separated from the glabella by a groove of medium width and depth. Glabella prominent, subquadrilateral, narrowing very slightly towards the broadly rounded front; three pairs of short obscure furrows occur well down toward the dorsal furrow surrounding the glabella; occipital ring well defined and bearing a spine that projects upward and backward. Fixed cheeks about one-half the width of the glabella and curving slightly downward from the glabella to the palpebral lobe; ocular ridge strong and extending to and connecting with the rim of the palpebral lobe; eye situated midway of the facial suture and rather prominent in size and position; postero-lateral limbs short, broad, and deeply grooved by the furrow within the posterior margin; at a point midway of the latter a broad angle is formed and a rudimentary spine indicated.

The direction of the facial suture is well shown in the figure of the head on the plate. A free cheek, associated in the same hand specimen of rock, shows a low visual surface for the eye, a marginal rim similar to that between the facial sutures, and a short spine at the postero-lateral angle.

The associated pygidium is moderately convex and bears a narrow, convex, median lobe, divided into five transverse segments and a short terminal segment; the lateral lobes are marked by four coalesced segments, indicating the continuation of the anterior segments of the median lobe; although broken by a smooth border, the seg-

ments may be traced into the four anterior of the six spines of the outer margin. Surface granulose under a strong magnifier.

A comparison with *Olenoides quadriceps* and *O. wasatchensis* (Bull. 30, U. S. Geol. Survey) shows a marked resemblance in the pygidia, but in the head certain differences occur, such as the narrower glabella and the wider furrow between the glabella and frontal rim of *O. fordi*.

The species referred to this genus from the American Cambrian strata are: *O. nevadensis* (the type), *O. marcoui*, *O. quadriceps*, *O. wasatchensis*, and *O. fordi*. In Bulletin 30, U. S. Geol. Survey, I referred *O. typicalis*, *O. ? flagricaudus*, *O. levis*, and *O. spinosus* to Olenoides, but they have since been included in the genus Zacanthoides.[1]

O. fordi is associated with *Olenellus asaphoides*, *Microdiscus connexus*, *Linnarssonia granvillensis*, etc.

The specific name is given in honor of Mr. S. W. Ford, who has done such excellent work at this horizon about Troy and Schodack Landing, N. Y.

Formation and localities.—Lower Cambrian; limestones interbedded in shaly slates, on the roadside just west of the Low Hampton crossing of the Poultney River, 2 miles south of North Granville and 1 mile north of Middle Granville, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17450.

OLENOIDES MARCOUI Whitfield.

(Pl. XCIV, figs. 2, 2*a*, *b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 186.

Nat. Mus. Cat. Invert. Foss., 15446.

OLENOIDES ELLSI, n. sp.

This species is represented by the head within the facial sutures, the separate free cheeks, a thoracic segment, the pygidium and the hypostoma. The head is semicircular in outline, rather strongly convex, and with the postero-lateral angles prolonged into sharp narrow spines; marginal rim narrow in front, wider at the sides, rounded and separated from the head by a narrow rounded groove; a strong furrow separates the narrow posterior rim from the body of the fixed cheek. Glabella elongate, sides subparallel and diverging slightly towards the broadly rounded front; surface convex and marked by three pairs of slightly defined glabellar furrows that do not unite at the center; in the smaller heads the posterior furrows are strongly marked and the two anterior pairs are scarcely perceptible, while in the adult the posterior pair are much like the two anterior pairs, except that they extend more obliquely backward;

[1] Am. Jour. Sci., 3d ser., vol. 36, 1888, p. 165.

a shallow, rounded pit occurs on the margin of the glabella and in the dorsal suture near the front angle that corresponds to a fourth pair of furrows; occipital ring strong and with a strong, sharp spine extending upward and backward from the center; occipital furrow well defined; dorsal furrows well defined on the sides and front of the glabella; fixed cheek of medium and nearly uniform width to where it merges into the strong postero-lateral limb; eye-lobe crescentiform, well defined from the cheek by a narrow groove that crosses the cheek to the dorsal furrow and separates off a narrow, short, ocular ridge; free cheek rather broad, moderately convex, and deeply cut to receive the base of the elongate, curved visual surface of the eye. The associated hypostoma is elongate, strongly convex, alate at the base and narrow in front; a small node occurs at the anterior third of the lateral margin, and the somewhat transverse frontal margin has a short spine at each lateral angle; a strong furrow separates the oval central portion from the margin back to the posterior third; a transverse furrow cuts across the anterior part of the body parallel to the rounded margin.

An associated thoracic segment has a rounded axial lobe with a base for a spine at the posterior center; the pleural lobe is bent backward half-way out from its base to the extremity; extremity not preserved; pleural groove broad and extending nearly to the end of the segment; anterior margin with a narrow facet that extends from the geniculation to the extremity.

Pygidium nearly semicircular; anterior margin broadly rounded; axial lobe narrow, convex, and divided into four rings, a frontal doublure and a terminal lobe, by five transverse furrows; lateral lobes divided by four furrows that extend obliquely backward to the broad denticulated margin; the four posterior annulations terminate before reaching the margin, while the narrow anterior one extends out as the frontal margin and passes into the anterior border spine; the flattened outer margin bears six short, rather sharp, flattened spines that extend backward on each side of the central axis; the posterior spine is the shortest and is nearly opposite the dorsal furrow, separating the axial and lateral lobes.

Surface of head, thorax, pygidium and hypostoma smooth, with the exception of some fine striæ on the rim of the head and the base of the hypostoma.

The species differs from described species in the details of the head and pygidium. The specific name is given in honor of Dr. R. W. Ells, of the geological survey of Canada, who guided me to the locality.

I found this species in a bowlder of the Sillery conglomerate. A number of heads, pygidia, and hypostomas were so associated that I think they belong to the one species. With them were two small species of Ptychoparia, a small Orthisina, like *O. transversa*, and a

fragment of a species of Stenotheca. As a whole the fauna is more like that of the Lower Cambrian than that of the Middle Cambrian, and, as far as known, this belt of conglomerate has afforded only Lower Cambrian fossils.

Formation and locality.—In a bowlder of the Sillery conglomerate, four miles below Quebec, Canada, on the south shore of the St. Lawrence River.

Nat. Mus. Cat. Invert. Foss., 18450.

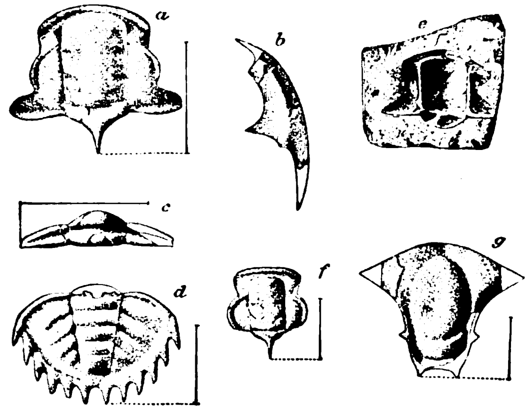

FIG. 66.—Olenoides ellsi; *a*, head within the facial sutures; *b*, interior of associated free cheek; *c*, thoracic segment; *d*, large pygidium; *e*, interior surface of a head that is longitudinally compressed; *f*, small head for comparison with FIG. *a*; *g*, enlargement of hypostoma; the outlined portions are taken from another specimen.

OLENOIDES (DORYPYGE) DESIDERATA, n. sp.

Head semicircular in outline, convex; marginal rim narrow in front, wider at the sides, and extended posteriorly into narrow, elongate, rounded spines at the union with the narrow posterior rim; within the marginal rim a narrow furrow separates the cheeks and glabella. Glabella subquadrangular, sides nearly subparallel in the larger, and slightly divergent anteriorly in the smaller specimens; surface convex and marked by three pairs of short furrows that divide the sides into four subequal lobes; occipital ring strong and provided with a short pointed spine extending upward and backward from the center; occipital furrow transverse and well defined; dorsal furrows of moderate depth at the sides of the glabella; fixed cheeks rather narrow at the eye-lobe and broader in front and back; eye-lobe about one-third the length of the head, crescentiform, and separated from the fixed cheek by a narrow groove that crosses the cheek just inside the short ocular ridge; free cheek subtriangular in outline, of medium convexity, and truncated on the inner side to support the visual surface of the eye.

Pygidium convex, semicircular, with a moderately rounded frontal

margin; axial lobe prominent, convex, and divided into five rings, a frontal doublure and a terminal lobe by six transverse furrows. A sixth ring is sometimes formed by the terminal lobe being cut across by a transverse furrow. A short spine has its origin at the center of each of the five rings; lateral lobes divided by five broad furrows that extend obliquely backward towards the margin; the frontal rim and the first anterior annulation cross the border and terminate in rounded spines that curve slightly backward; the remaining annulations merge with the furrows into a broad, companulate margin that extends out back of the pygidium and rounds in nearly to the base of the axial lobe at the center. The undulation at the center, and also at the middle of the margin, varies considerably in different specimens. In some of the smaller pygidia the posterior margin closely resembles that of *Protypus senectus*, while in the larger it is more like that of *Dicellocephalus misa* of the Upper Cambrian.

Surface of glabella strongly granulose, with the granulations arranged in obscure lines parallel to the sides; surface of fixed and free cheeks and pygidium granulose.

The head of this species is much like that of *O.* (*Dorypyge*) *richthofeni* Dames[1] and it has a similarly granulated test. The associated pygidium differs from that of *O.* (*Dorypyge*) *richthofeni* in having an expanded instead of a spinous posterior margin. It may be desirable to distinguish the species with a granulose from those with a smooth test; if so, the former may be grouped under Dorypyge as a subgenus of Olenoides.

Formation and locality.—Lower Cambrian; limestone and calcareous sandstone, one and one-half miles east-southeast of Highgate Springs, Vt.

Nat. Mus. Cat. Invert. Foss., 18452.

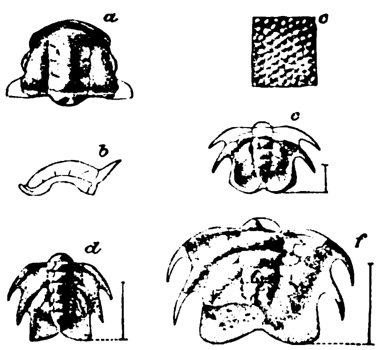

FIG. 67.—Olenoides (D.) desiderata: *a*, Head within the facial sutures; *b*, side view of head and occipital spine; *c*, enlargement of the pustulose surface of the head; *d*, pygidium, compressed laterally; *e*, a small pygidium, showing the broad, thickened, posterior margin; *f*, the largest pygidium found.

[1] China. Richthofen, vol. 4, 1883, p. 24.

OLENOIDES QUADRICEPS H. & W.

(Pl. XCIV, figs. 4, 4*a–d*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 187.

This is one of the few species that ranges from the Lower Cambrian up into the Middle Cambrian.

Nat. Mus. Cat. Invert. Foss., 15449.

ZACANTHOIDES Walcott.

See Am. Jour. Sci., 3d series, vol. 36, 1888, p. 165.

ZACANTHOIDES LEVIS Walcott.

(Pl. XCIV, figs. 5, 5*a*.)

Described as *Olenoides levis*. Bull. U. S. Geol. Survey, No. 30, 1886, p. 187.
Nat. Mus. Cat. Invert. Foss., 15445.

ZACANTHOIDES EATONI Walcott.

(Pl. XCIV, fig. 6.)

Zacanthoides eatoni Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, p. 45.

This species differs from *Zacanthoides levis* in having the glabella clavate instead of subcylindrical; also in the more elongate form of the head. Pygidium unknown.

Nat. Mus. Cat. Invert. Foss., 18362.

BATHYNOTUS Hall.

BATHYNOTUS HOLOPYGA Hall.

(Pl. XCV, figs. 1, 1*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 191.
Nat. Mus. Cat. Invert. Foss., 15409.

AVALONIA Walcott.

AVALONIA MANUELENSIS Walcott.

(Pl. XCV, figs. 3, 3*a*.)

Avalonia manuelensis Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, p. 44.

As the types of the genus and species are the same, one description only will be given.

The genus and species are founded on the central portion of the head of a trilobite, that differs from any described species known to me in the form of the dorsal and ocular furrows and fixed cheek.

Head semicircular, moderately convex. Glabella subquadrangular, slightly convex; sides parallel; three pairs of narrow, shallow furrows divide the glabella into four subequal lobes; the two posterior furrows extend about one-third the distance across the glabella, the anterior pair being very short and indistinct. Occipital ring narrow, transverse, and separated from the glabella by a strong furrow. The dorsal furrows are well defined grooves, extending from the posterior margin to the frontal rim. Fixed cheeks broad, very slightly convex; the anterior fourth is separated by a narrow furrow that starts at a slight deflection in the glabellar suture, and extends outward and backward to the facial suture, where it passes into what, in many trilobites, is the furrow on the eye-lobe. This furrow, or groove, occupies the position of the ocular ridge from the dorsal furrow to the facial suture. The extension of the furrow backward joins the furrow extending from the occipital furrow outward, just inside the posterior margin. Frontal margin of medium width and separated from the glabella by a strong furrow; posterior rim of the head narrow, rounded, and separated from the fixed cheek by a strong furrow that unites at the postero-lateral angle with the furrow on the outer edge of the fixed cheek. The eye-lobe is not distinctly shown in any of the specimens. If present, it is probably long and narrow, as in the genus Centropleura of Angelin or Anopolenus of Salter. Surface reticulated with fine, inosculating, raised lines as shown by Fig. 3*a*. If the surface is partially worn it has a punctate appearance.

Free cheeks unknown. From the form of the fixed cheeks they were evidently long and narrow. The broad fixed cheek, with its furrows on the lateral and posterior margins, recalls the cheek of Anopolenus, while the quadrangular glabella is that of the genus Olenoides. As far as known to me, the depressed ocular furrow is peculiar to the genus.

Formation and locality.—Lower Cambrian; in a railway cut about 600 meters north of Manuel's Brook, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18333.

CONOCORYPHE Corda.

CONOCORYPHE TRILINEATA Emmons.

(Pl. XCV. figs. 5, 5*a*–*e*)

See Bull. No. 30, U. S. Geol. Survey, p. 203, and Am. Jour. Sci., 3d series, vol. 34, p. 197, 1887.

Since the publication of the description and figures in Bulletin 30, in 1886, and the American Journal of Science, in 1887, I have secured very perfect specimens from the original locality. These show the

generic identity of the species with *Conocoryphe sulzeri* Barr, as restricted by Corda.[1]

On Plate xxvii, Bull. 30, U. S. Geol. Survey, Figs. 1*a*, 1*b*, there are figures drawn by Mr. Ford of the species as identified by him at Troy, N. Y. The pygidium is similar to that associated with *Solenopleura ? nana* at other localities, and the head may be that of this species, but it is uncertain, owing to the imperfection of the specimens.

Formation and localities.—Lower Cambrian; in black, argillaceous, shaly slate, on the roadside near the old Reynolds Inn, now D. W. Reid's farm buildings, about one mile west of North Greenwich; also in the northern part of Easton, about one mile south-southwest of the village of Greenwich, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17453.

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[1] Mr. S. W. Ford states that this species has been shown to belong to the genus Conocoryphe (Am. Jour. Sci., III, vol. xix, p. 152), but up to the present time I have not seen any proof of its true generic relations, nor could it well be shown before more perfect specimens of the head were obtained than those illustrated by Emmons.

The genus Atops was proposed by Dr. Emmons, in 1844, for the head of a trilobite which "seemed to belong to an intermediate genus between Calymene and Triarthrus." The head and three segments of the body are preserved in the specimens figured, as shown in an accompanying illustration. He says of it: "No 1, I have named *Atops trilineatus*. The absence of eyes, however, is not a distinctive mark; the three species are blind. The *Atops* is evidently allied to the *Triarthrus beckii*, so abundant in the Utica slate; the lines in this, however, are direct or transverse to the middle lobe; there is an additional pair in the *Atops*." (The Taconic System, Albany, 1844, p. 20.)

When Professor James Hall studied the faunas of the Lower Paleozoic rocks of New York he had the type specimen of *Atops trilineatus* before him, as figured by Emmons, and he concluded that it was a specimen of *Triarthrus beckii* of the Utica shale. In 1848 Haldeman recognized the species as distinct from *Triarthrus beckii*. (Am. Jour. Sci., 2d series, vol. 5, p. 107.)

Before the publication of Part II of the "American Geology" by Emmons, in 1856, he discovered more perfect specimens of the species, which show without question that it is distinct from *Triarthrus beckii*. Prior to this, however, Corda had described the genus Conocoryphe, which as we now know, is identical with Atops. There does not appear to have been sufficient data for the correct generic determination of the genus Atops until 1886, when it was shown to be identical with Conocoryphe, published in 1847 by Corda. (Am. Jour. Sci., 3d series, vol. 34, 1887, p. 197.) If the genus Atops is to be recognized it replaces Conocoryphe, as the two genera are identical.

It appears to me that if a genus is so badly defined and illustrated that its generic characters were unknown and unrecognized until perfect specimens of the type species were discovered, and this nearly forty years after an identical genus had been well defined, it would be straining the law of priority to an unwarrantable extent to insist upon its recognition.

CONOCORYPHE RETICULATA, n. sp.

(Pl. XCV, figs. 6, 6*a*.)

Head transversely subcircular; surface unequally trilobate, somewhat convex; marginal rim of medium width, continuous, separated from the body of the head by a marked groove all around, except in front of the glabella, where it is narrower and less strongly defined. Glabella with subparallel sides that converge slightly toward the rounded frontal margin; surface convex and broken by three pairs of narrow, well defined furrows that extend obliquely backward, subparallel to each other, to the central third of the surface; frontal lobe strongly defined, rounded but not raised above the general sur-surface of the glabella; second and third lobes narrow, subparallel; posterior lobe with a narrow center, uniting the subtriangular lateral lobes. Occipital ring of medium width, with the occipital furrow uniting with the marginal sulcus back of the cheeks.

The cheeks are moderately convex, subtriangular in outline, and unbroken by facial sutures or eye-lobes; a pseudo-ocular ridge curves from a point in front of the anterior glabellar furrow, first forward and then outward and backward to where it is lost in the marginal sulcus. The surface of the cheeks is covered with a fine network of irregularly inosculating raised lines; on the marginal rim the lines are more regular and the meshes of the network are elongated; the surface of the glabella is smooth with the exception of fine raised lines on the anterior portion.

This species is clearly distinct from described forms. Its surface ornamentation is unique in the Conocephalidæ, and approaches that of *Olenellus* (*M.*) *asaphoides*, with which it is associated.

Formation and locality.—Middle portion of the Lower Cambrian; northwest side of the village of Salem, Washington County, N. Y.

PTYCHOPARIA Corda.

PTYCHOPARIA ADAMSI Billings.

(Pl. XCVI, figs. 1, 1*a*–*c*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 195.

Nat. Mus. Cat. Invert. Foss., 15435.

PTYCHOPARIA ? ATTLEBORENSIS S. & F.

(Pl. XCV, fig. 2.)

Ptychoparia attleborensis Shaler & Foerste, 1888. Bull. Mus. Comp. Zool., Harvard College, vol. 16, p. 39, Pl. ii, Fig. 14.

"Head small, often minute; in the largest specimen 4^{mm} long. The usual size is about 2.6^{mm}. The glabella is oblong or slightly attenu-

ate anteriorly. The occipital groove is low or indistinct. The occipital ring extends beyond the general posterior outline of the head, and apparently forms part of the glabella before it. The glabella is sometimes intersected by faint lateral grooves, of which there are three pairs, the anterior pair scarcely visible; oftener these grooves are obsolete, and the glabella may, in case the occipital groove is very slight, appear as a continuous undivided body as far as the posterior margin of the head. The glabella is always convex and considerably elevated above the general level of cheeks. There is in some specimens a very slight trace of an ocular ridge, which runs from the anterior end of the glabella laterally and slightly posteriorly, joining a similar slight trace of the palpebral lobes. The most marked feature of the fixed cheeks is the existence of a depression along their postero-lateral outline. The anterior border is proportionately very broad. About the character of the rim little can be said. Near the lateral margin of the border, or rather near the facial suture, there are sometimes two or three low tubercles visible. There is also in some specimens a faint trace of a sufficient elevation of the border to indicate an incipient marginal rim. A careful comparison of these specimens with published figures of *P. subcoronata* Hall & Whitfield, a specimen of similar size, shows numerous differences, which are too marked to permit the Attleborough specimens to be placed under the same species.

"*Locality and position.*—Station No. 2, North Attleborough, Mass.; Cambrian; 20 specimens."

This species also occurs at the lowest horizon of the Olenellus zone, on Manuel's Brook, in Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18332.

PTYCHOPARIA ? FITCHI Walcott.

(Pl. XCVI. fig. 5.)

Ptychoparia fitchi Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, p. 197, Pl. i, Fig. 6.

This species is founded on a minute head that occurs in association with *Microdiscus connexus* and several other species of the lower horizon of the Lower Cambrian slate series. The elongate, unfurrowed glabella, wide fixed cheeks, and strongly granulose surface, all unite to give it a facies unknown in any other species with which I am acquainted.

Formation and locality.—Lower Cambrian; in limestone interbedded in the shaly slates, 2 miles south of North Granville, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17455.

PTYCHOPARIA MISER Billings.

(Pl. XCVI, fig. 8.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 199.
Nat. Mus. Cat. Invert. Foss., 15444.

PTYCHOPARIA METISENSIS, n. sp.

Head convex, semicircular in outline. Glabella convex, truncato-conical, tapering gradually to the rounded front, a little longer than wide at the occipital furrow and marked by three pairs of slightly impressed furrows; the posterior pair extends obliquely inward a short distance and then each connects by a smooth surface on the granulated shell, with a round, shallow depression situated directly back of its termination; the two anterior pairs trend slightly backward. Occipital furrow deep, arching forward a little at the center; occipital segment strong, rounded, broadest at the center and narrowing towards the sides; dorsal furrows strongly defined. Fixed cheeks relatively narrow; anteriorly they widen and merge into the frontal limb, and posteriorly into the postero-lateral limbs. Frontal limb at the center about as long as the width of the rounded frontal limb. Postero-lateral limbs strong and marked by the broad, rounded posterior marginal furrow of the head. Palpebral lobes narrow, rather long, and confluent with the ocular ridge that crosses to the dorsal furrow near the anterior end of the glabella. The course of the facial sutures is shown in the accompanying figure of the head. The associated free cheek has a strong marginal border that is prolonged into a rather stout spine; central area moderately convex. The broad marginal border in the figure results from the position in which the cheek was viewed by the draughtsman.

Thorax unknown.

Pygidium semicircular in outline, moderately convex; axial lobe prominent, truncato-conical above and merging into the marginal rim at its base, divided into five rings by four narrow transverse furrows, the two anterior of which are well defined; the posterior ring has two small nodes upon it in some specimens; the lateral or pleural lobes are grooved by about three rather broad furrows that separate ridges, which unite with the strong, rounded marginal border.

Surface of head and pygidium finely granulose. On the central area of the free cheeks the granulations are much larger. The larger heads vary in length from 10^{mm} to 12^{mm}.

This species is allied to *P. granulosus* H. & W. of the Upper Cambrian of Nevada, but differs in character of granulation and details of head. It was found by Sir William Dawson in a limestone bowlder of the conglomerate at Metis. No other species are associated with it; but from the fact that all the species known to

me from the bowlders in the conglomerates of Bic, St. Simon, and Metis belong to the Lower Cambrian fauna, this is considered as *probably* of the same age.

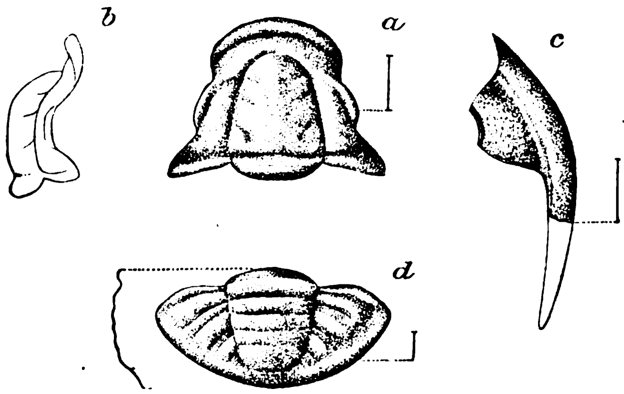


FIG. 68.—PTYCHOPARIA METISENSIS.

FIG. 68*a*. Enlargement of central portion of head.
FIG. 68*b*. Outline side view of fig. 68*a*
FIG. 68*c*. Enlargement of free cheek. The specimen is represented as it lies flat in the rock and thus the margin is too broad as compared with that of the head.
FIG. 68*d*. Enlargement of pygidium.

Collection: Peter Redpath Museum, McGill College, Montreal, Canada.

Formation and locality.—In a bowlder of limestone supposed to be of Lower Cambrian age, in conglomerate at Metis, province of Quebec, Canada.

Nat. Mus. Cat. Invert. Foss. 23838.

PTYCHOPARIA SUBCORONATA H. & W.

(Pl. XCVI, fig. 6.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 205.

Specimens that are apparently identical with the types from Utah occur in the upper part of the Olenellus zone, in Washington County, N. Y. This gives a wide geographic range to the species, but with our present material it is impossible to separate the specimens collected from the distant localities.

Nat. Mus. Cat. Invert. Foss., 15442.

PTYCHOPARIA TEUCER Billings.

(Pl. XCVI, fig. 3.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 197.

Nat. Mus. Cat. Invert. Foss., 15436.

Ptychoparia vulcanus Billings.

(Pl. XCVI, figs. 4, 4*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 198.
Nat. Mus. Cat. Invert. Foss., 15437.

CREPICEPHALUS Owen.

Crepicephalus augusta Walcott.

(Pl. XCVI, figs. 9, 9*a–b*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 208.
Nat. Mus. Cat. Invert. Foss., 15430.

Crepicephalus liliana Walcott.

(Pl. XCVI, figs. 7, 7*a–c*.)

See Bull. U. S. Geol. Survey, No 30, 1886, p. 207.
Nat. Mus. Cat. Invert. Foss., 15428.

Oryctocephalus primus Walcott.

(Pl. XCV, figs. 4, 4*a*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p 210.
Nat. Mus. Cat. Invert. Foss., 15427.

ANOMOCARE Angelin.

Anomocare ? parvum Walcott.

(Pl. XCVI, fig. 2.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 209.
Nat. Mus. Cat. Invert. Foss., 15426.

AGRAULOS Corda.

Agraulos strenuus Billings.

(Pl. XCVII, figs. 1, 1*a–c*.)

Agraulos strenuus, Billings, 1874. Geol. Survey Canada; Pal. Foss., vol. 2, part 1, pp. 71–72.

"Head (without the movable cheeks) irregularly quadrangular, broadly rounded in front. Glabella rather strongly convex, conical, variable in its proportional length and width, either smooth or with several obscure impressions on each side representing the glabella furrows; neck segment with a strong triangular projection backward; neck furrows all across, but usually obscurely impressed. In some specimens the front of the head has a thick convex marginal rim separated from the front of the glabella by a narrow

groove. In others this rim is scarcely at all developed. The eyes, shown by the form of the lobe, appear to have been semi-annular and about one-third the length of the head. The surface appears to be smooth. The following are the dimensions of the best preserved specimen:

"Length of the head, including the large posterior projection, six lines; width of the convex marginal rim, one line; width of the groove between the rim and the front of the glabella, one-third of a line; length of the glabella, including the projection, five and two-thirds lines; width of the glabella at the posterior margin, three lines; width of the fixed cheek from the center of the edge of the eye-lobe to the side of the glabella, two lines. A line drawn across the head at two and a quarter lines from the front margin would pass through the anterior angles of the eyes. The length of the eye appears to be nearly two lines.

"As above remarked, this species varies somewhat in its proportional length and width, and hence the dimensions above given would not be found to be exactly parallel in all the specimens.

"Occurs in the gray limestone of Topsail Head and also in the pinkish limestone of Brigus, Conception Bay."

Ptychoparia mucronatus Shaler & Foerste[1] appears to be identical with this species when a comparison is made between the respective types from Newfoundland and Massachusetts.

Nat. Mus. Cat. Invert. Foss., 18334.

AGRAULOS STRENUUS var. NASUTUS, n. var.

(Pl. XCVII, figs. 2, 2*a*–*c*.)

This variety of *A. strenuus* has a broad, extended frontal limb, that gives a marked character to the head. It occurs in association with *A. strenuus* at the base of the Olenellus zone at Manuel's Brook, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18335.

AGRAULOS REDPATHI, n. sp.

Glabella and fixed cheeks convex, rhomboidal in outline. Glabella converging slightly from the base to its broadly rounded, truncated frontal margin; length and greatest width at the occipital furrow subequal; marked by two pairs of slightly impressed furrows. Occipital furrow relatively broad and deep, arching forward at the center; occipital ring tumid, round and broad at the center, tapering so rapidly towards the sides that it does not equal the width of the glabella. Dorsal furrow distinct. Fixed cheeks broad, rising rapidly from the facial suture and graduating into the frontal limb

[1] Bull. Mus. Comp. Zool., Harvard College, vol. 16, 1888, p. 37.

anteriorly and into the short, postero-lateral limbs at the back. Frontal limb rather broad and separated from the partially defined frontal rim by two faint grooves that do not unite at the center. Postero-lateral limbs scarcely defined from the fixed cheeks; a strong furrow crosses from their outer margin to the base of the glabella. Palpebral lobes narrow, short, and confluent anteriorly with the ocular ridges that cross the cheeks to the dorsal furrow nearly opposite the anterior end of the glabella. The facial sutures have the direction shown in the accompanying figure.

Free cheeks, thorax, and pygidium unknown.

Surface apparently smooth.

This small species is strongly distinct from other forms found associated with the Lower Cambrian fauna. The specimen figured is the interior cast of the shell. The exterior of the shell scarcely shows the glabellar furrows, ocular ridge, and the groove separating the frontal limb and margin.

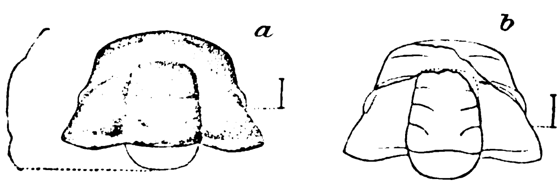


FIG. 69.—AGRAULOS REDPATHI, n. sp. *a*, Enlarged figure of the central portion of the head. Collection Peter Redpath Museum, McGill College, Montreal, Canada; *b*, outline view of a more convex specimen preserving a portion of the outer shell.

Formation and locality.—Lower Cambrian; associated with Olenellus in limestone bowlder of conglomerate at St. Simon, province of Quebec, Canada.

Nat. Mus. Cat. Invert. Foss., 23839. This is a plaster cast and matrix of the head.

PROTYPUS Walcott.

PROTYPUS HITCHCOCKI Whitfield.

(Pl. XCVIII, fig. 6.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 211.

Nat. Mus. Cat. Invert. Foss., 15424.

PROTYPUS SENECTUS Billings.

(Pl. XCVIII, figs. 7, 7*a*–*c*.)

See Bull. U. S. Geol. Survey, No. 30, 1886, p. 213.

Nat. Mus. Cat. Invert. Foss., 15421.

PROTYPUS CLAVATUS Walcott.

(Pl. XCVIII, fig. 4.)

Ptychoparia ? (subgenus?) *clavata* Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, p. 198, Pl. i, Fig. 3.

This is a minute trilobite, whose true relations are unknown. With the exception of its clavate glabella, it is related to *Solenopleura ? nana* and *S. ? tumida* by the course of the facial sutures, wide fixed cheeks, and small eye-lobes.

Formation and localities.—Lower Cambrian; limestones interbedded in the shaly slates, one and one-quarter miles south of North Granville, on the roadside a little north of school-house No. 4, in the northeast part of Whitehall; on the roadside just west of the Low Hampton crossing of the Poultney River; and near Rock Hill schoolhouse (No. 8), about one mile east of North Greenwich, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17454, 17487.

SOLENOPLEURA Angelin.

SOLENOPLEURA BOMBIFRONS Matthew.

(Pl. XCVIII, figs. 5, 5*a*, *b*.)

Solenopleura bombifrons Matthew, 1887. Trans. Roy. Soc. Canada, 1887, vol. 4, sec. 4, p. 156.

This species was founded on a small head from the limestone at Topsail Head, Conception Bay, Newfoundland. I found other specimens at the same locality, and also at Manuel's Brook, two miles north, in association with *Olenellus* (*M.*) *bröggeri*. The larger specimens vary in details from the type, but they are connected with it by forms, graduating in size down to that of the type.

Nat. Mus. Cat. Invert. Foss., 18337.

SOLENOPLEURA ? HARVEYI Walcott.

(Pl. XCVII, figs. 7, 7*a*.)

Solenopleura harveyi Walcott, 1889. U. S. Nat. Mus. Proc., vol. 12, p. 45.

Of this species only the central portions of the head have been found. These belong to a very large species, as the heads vary in length from 40^{mm} to 45^{mm}.

The glabella is conical, about twice as long as wide, and separated from the slightly rounded occipital ring by a shallow furrow. Two very shallow furrows extend obliquely backward from the dorsal furrow on each side, and scarcely indent the smooth convex surface of the glabella. An anterior pair of furrows are indicated by a short, shallow depression on a line with the anterior margin of the eye-

lobe. The glabella is separated from the fixed cheeks and frontal limb by a shallow groove on the sides, and in front it is separated by the difference in slope of its surface and that of the frontal limb. Frontal limb broad and gently convex down to the slight depression separating it from the relatively broad depressed margin; laterally, it passes into the broad, smooth, free cheeks. The frontal margin of the eye-lobe is at about half way between the posterior and anterior margins of the head, and is of medium size. A well defined ocular ridge extends obliquely backward across the fixed cheek, from the glabella to the eye-lobe. The posterior margin of the head is separated from the main part of the fixed cheek by a broad, shallow groove.

With the material at hand for study, the species is referred provisionally to Solenopleura.

The specific name is given in honor of Rev. M. Harvey, the author of the best work yet published on Newfoundland and the enthusiastic helper of every scientific student who visits the colony.

Formation and locality.—Lower Cambrian; about 600 meters north of Manuel's Brook, Conception Bay, Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18338.

SOLENOPLEURA? HOWLEYI Walcott.

(Pl. XCVII, figs. 8, 8*a*.)

Solenopleura howleyi Walcott, 1889. U.S. Nat. Mus. Proc., vol. 12, pp. 45, 46.

A second large species is referred to Solenopleura. It is associated with *S. harveyi*, and is much nearer the types of the genus Solenopleura than the latter species. It is known only by the central portion of the head and a few segments of the thorax.

The glabella is elongate, conical, convex, and marked by three pairs of shallow furrows that penetrate obliquely backward one-third of the distance across the glabella; occipital ring rounded and well defined from the glabella by a deep furrow; a small node occurs at the center; the glabella rises rather abruptly from the broad, slightly convex, fixed cheeks and narrow frontal limb, a shallow dorsal furrow serving to give it more prominence. The broad fixed cheeks are crossed by a narrow ocular ridge that passes obliquely outward and backward, from a point on the dorsal furrow, opposite the anterior fourth of the glabella, to the anterior margin of the eye-lobe, where it unites with the outer rim of the rather large, prominent eye-lobe. Anterior rim of the head of medium width, rounded and separated from the frontal lobe by a narrow, distinct furrow. The posterior rim or margin is more rounded than the anterior, and the furrow defining it is deeper. The short postero-lateral limb of the fixed cheek slopes abruptly down to its half truncated margin.

Surface strongly granular or pustulose.

Formation and locality.—Lower Cambrian; associated with *Solenopleura ? harveyi.*

The specific name is given in honor of Mr. James P. Howley, geologist of Newfoundland.

Nat. Mus. Cat. Invert. Foss., 18336.

SOLENOPLEURA ? NANA Ford.

(Pl. XCVIII, figs. 1, 1*a*–*e*, 2.)

Solenopleura nana Ford, 1878. Am. Jour. Sci., 3d series, vol. 15, p. 126; Walcott, 1886. Bull. 30, U. S. Geol. Survey, p. 214.

Solenopleura ? nana Walcott, 1887. Am. Jour. Sci., 3d series, vol. 34, p. 196; Pl. i, Figs. 1–1*d*

This species was not illustrated by Mr. Ford, and the specimens I had when preparing Bulletin 30, U. S. Geol. Survey, were so poor that the illustrations then given were not satisfactory. Among the specimens in the collections from Washington County I find considerable variation in the convexity of the glabella and also in the granulose surface; and I suspect that with a large series of more perfect specimens there could be separated a variety if not a distinct species. The pygidium associated with *S.? nana* at Troy and also in Washington County, 2 miles south of North Hebron and 1 mile north of Middle Granville, has a spinose margin that recalls the pygidæ of certain species of Peltura from the Swedish Cambrian.

Nat. Mus. Invert. Foss., 15425.

SOLENOPLEURA ?? TUMIDA Walcott.

(Pl. XCVIII, figs. 3, 3*a*.)

Solenopleura ?? tumida Walcott, 1887. Am. Jour. Sci., 3d ser., vol. 34, p. 196, Pl. i, Figs. 2–2*a*.

This species differs from *Solenopleura ? nana*, with which it is associated at several localities, in having a more tumid glabella, narrower frontal lobe, and in the absence of an ocular spine. Some specimens of *S. ? nana* have almost as tumid a glabella, but usually it is less elevated.

The generic reference is provisional, as both *S. ? tumida* and *S. ? nana* appear to belong to a genus distinct from the typical species of Solenopleura.

Formation and localities.—Lower Cambrian. Limestones, interbedded in the shaly slates near Rock Hill school-house (No. 8), east of North Greenwich; 1½ miles east and 3 miles northeast of North Greenwich; on the west side of D. W. Reid's farm, about 1½ miles west of North Greenwich; one-half a mile east of South Hartford post-office; in the village of East Hebron; on the roadside just west of Low Hampton crossing of the Poultney River and 1 mile south of Shushan, Washington County, N. Y.

Nat. Mus. Cat. Invert. Foss., 17452.

PLATES.

PLATE XLIX.

PLATE XLIX.

SPONGIÆ.

PLATE L.

PLATE L.

FIG. 1. A portion of a transverse section from the type specimen 1*e*, showing the characters of the primary and supplementary layers of the wall laminæ. (After Hinde.) Enlarged ten diameters.

1*a*. Portion of a transverse section, showing the arrangement of the laminæ of the wall; for the most part irregular, but apparently radial in some places. From the type specimen. (After Hinde.) Enlarged four diameters.

1*b*. Longitudinal section of a specimen from Silver Peak, Nevada.

1*c*. Longitudinal section showing more regularity in the arrangement of the skeleton than in the type specimen, Pl. L, fig. 1*f*. Collection U.S. National Museum.

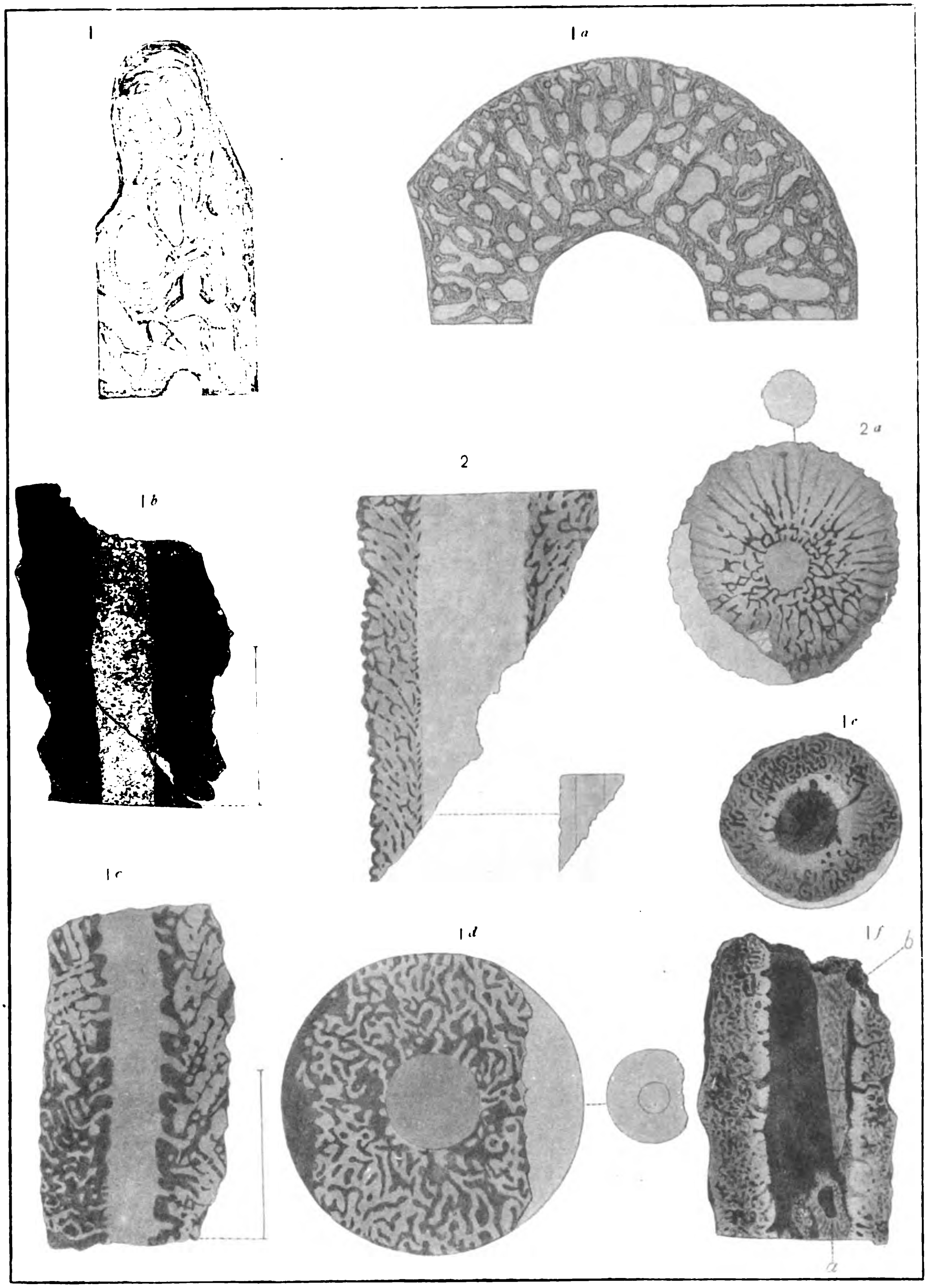
1*d*. Transverse section of specimen from L'Anse au Loup, Labrador, enlarged to show the irregular openings. Collection U.S. National Museum.

1*e*. Transverse section of the type specimen now in the museum of the Geological Survey of Canada.

1*f*. Longitudinal section of 1*e*. At *a* the growth within the cup, spoken of in the text, is shown. The elongate body, *b*, is probably a foreign body introduced into the cup.

2. Longitudinal section of specimen from Silver Peak that shows still more regularity in the interior structure than either 1*b* or 1*f*. Collection U.S. National Museum.

2*a*. Transverse section of Fig. 2.



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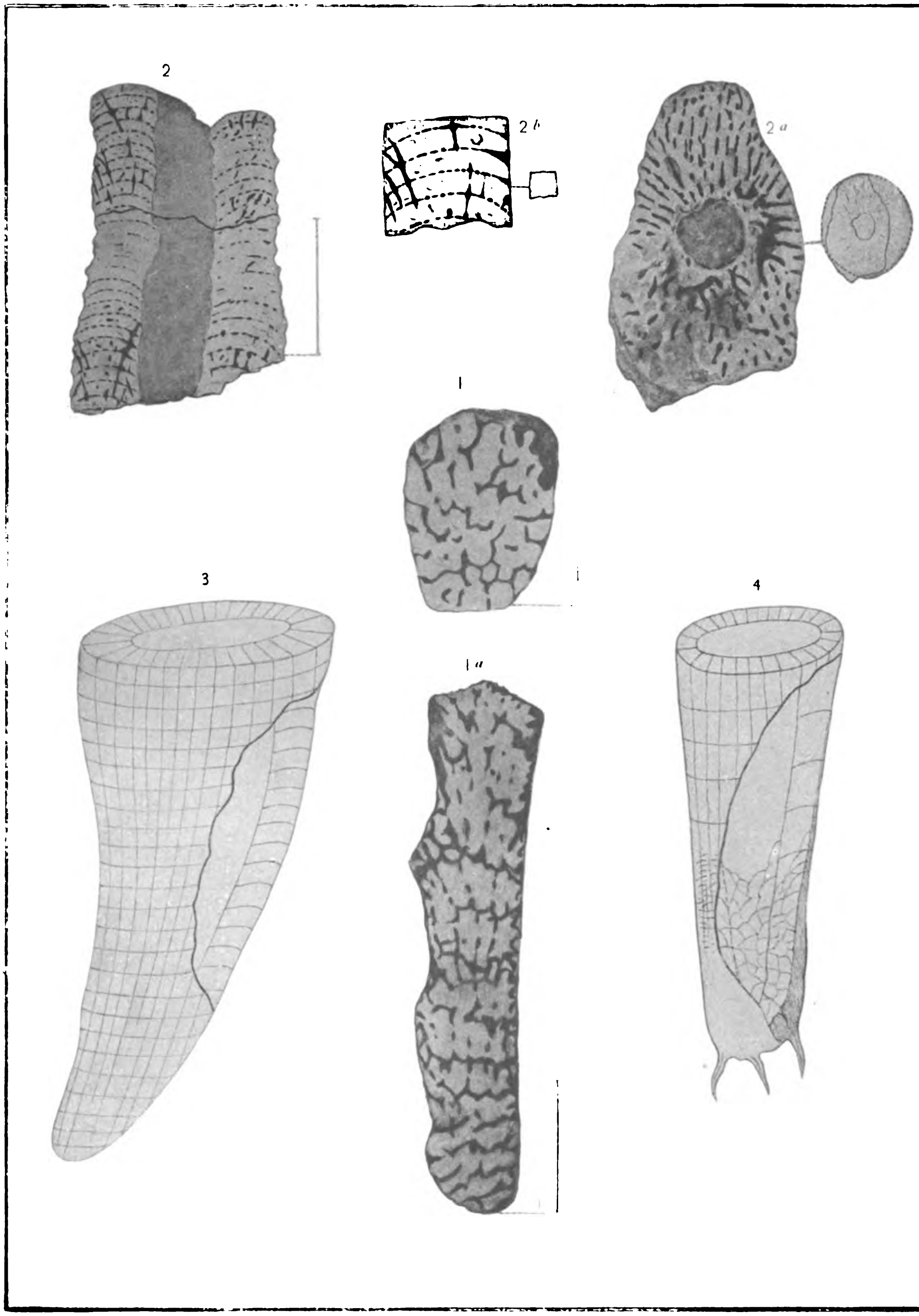
ACTINOZOA.

PLATE LI.

PLATE LI.



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ACTINOZOA.

PLATE LII.

PLATE LII.

	Page
ARCHÆOCYATHUS PROFUNDUS	600

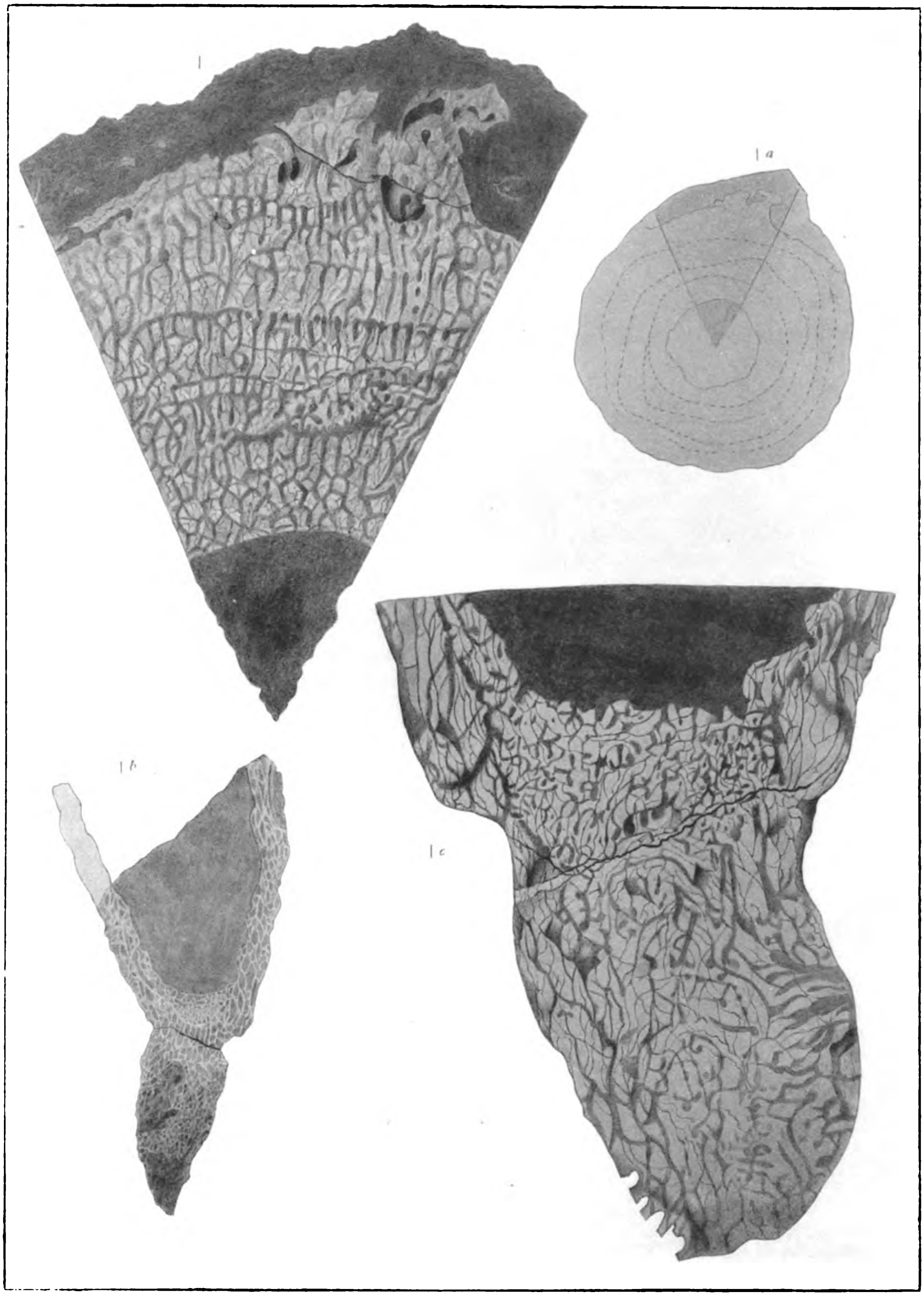
FIG. 1. Enlargement of a portion of a transverse section of specimen in which the growth appears to have been in layers. Collection U. S. National Museum.

1*a*. Outline of the section from which Fig. 1 was enlarged.

1*b*. Longitudinal section showing the depth of the cup and the vesiculose character of the space between the walls. An enlarged view of the lower portion of this figure is shown by Fig. 1*c*. Collection U. S. National Museum.

1*c*. Enlargement of a portion of the section shown by Fig. 1*b*. The vesiculose structure is well shown. Collection U. S. National Museum.

See Pls. LIII and LIV.



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ACTINOZOA.

PLATE LIII.

Plate LIII.

	Page.
Archæocyathus profundus	600

Fig. 1. Enlargement of a portion of the section represented by Fig. 1, Pl. LII, to show the radial septa and the dissepiments.

1*a*. Portion of a longitudinal section of the wall showing, in places, the perforations in the septa and the dissepiments. (After Hinde.) Enlarged five diameters.

1*b*. View of the cup of a small specimen. Collection U. S. National Museum.

See Pls. LII and LIV.

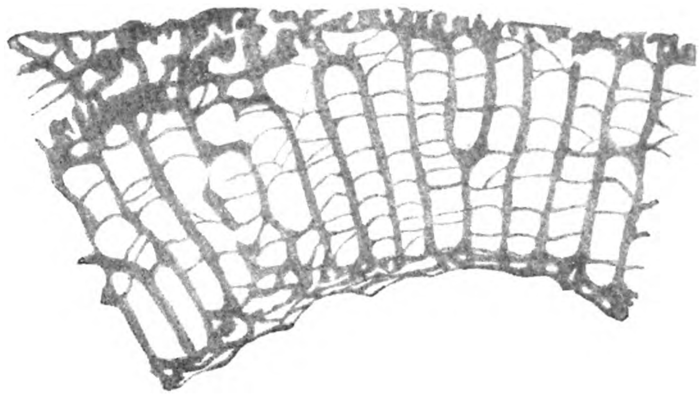
Ethmophyllum marianus	601

Fig. 2. Enlargement to show the septa and poriferous outer wall. (After Roemer.) See Pl. LV, figs. 3, 3*a-c*

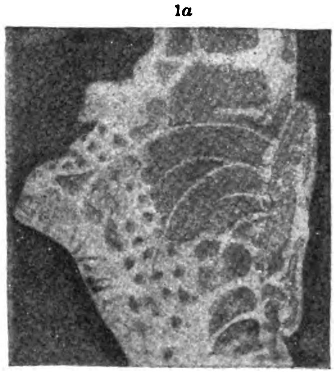
Ethmophyllum	601

Fig. 3. Diagrammatic section of the inner and outer wall and the longitudinal septa. The plates on the inner wall are not represented.

1



1a



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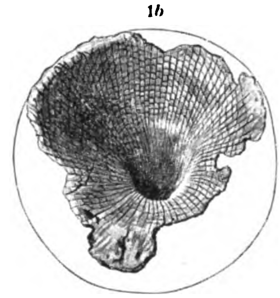

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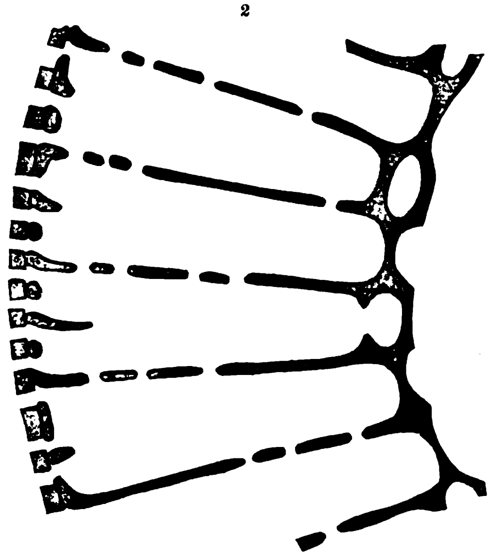

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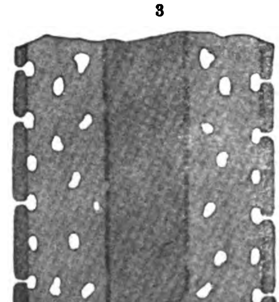


ACTINOZOA.

PLATE LIV.

PLATE LIV.

Page.

ARCHÆOCYATHUS (A.) RENSSELÆRICUS 600

FIG. 1. A nearly perfect specimen, showing the summit and the outer poriferous surface. Collection U. S. National Museum.

1*a*. A specimen with portions of outer wall removed, so as to show the septa and the poriferous surface of the inner wall. Collection U. S. National Museum.

1*b*. Transverse section, showing 12 septa and the pores of the inner and outer walls, enlarged. Collection U. S. National Museum.

1*c*. Transverse section of the upper end of 1*a*, with 18 septa. Collection U. S. National Museum.

1*d*. Transverse section where the walls and septa are thickened by additional layers. Collection U. S. National Museum.

1*e*. Enlargement of the outer poriferous surface.

ARCHÆOCYATHUS (A.) RARUS 601

FIG. 2. View of the only specimen that can be referred to this species in the collection. The outer surface is entirely removed. Collection U. S. National Museum.

2*a*. Transverse section of the lower end of 2, showing 9 septa.

2*b*. Drawing of the type specimen, by Mr. S. W. Ford. There are about 21 septa and the outer surface is removed. Collection S. W. Ford.

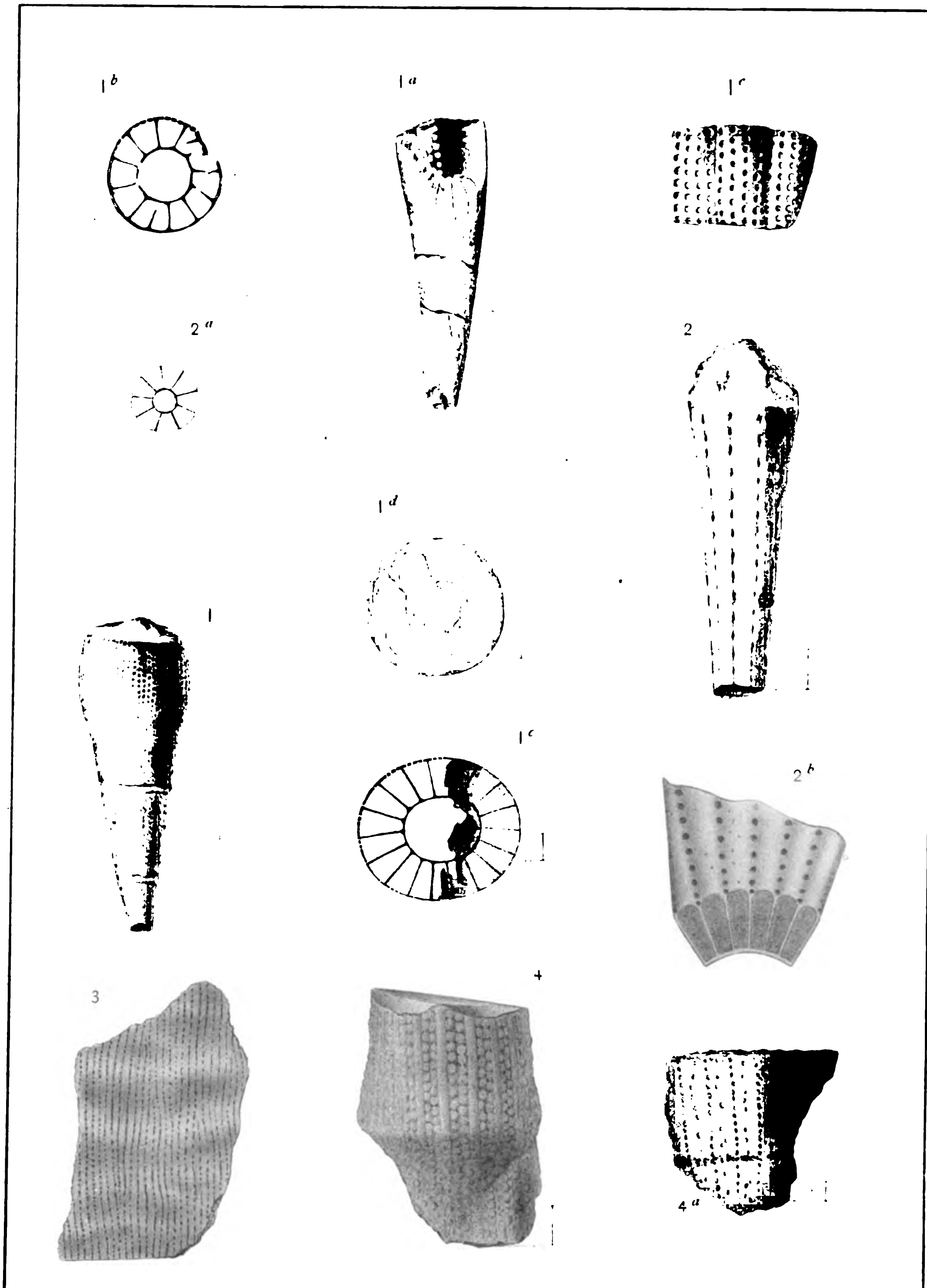
ARCHÆOCYATHUS PROFUNDUS 600

FIG. 3. Portion of a cast of the interior portion of the outer wall, showing the openings in the septa. Collection U. S. National Museum. See Pls. LII and LIII.

ARCHÆOCYATHUS DWIGHTI 601

FIG. 4. Cast showing the arrangement of the pores and the longitudinal grooves.

4*a*. A specimen provisionally referred to this species. It may be a fragment of the outer wall.



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ACTINOZOA.

PLATE LV.

PLATE LV.

	Page.
ETHMOPHYLLUM WHITNEYI	601

FIG. 1. Enlargement to two diameters of one of the type specimens. Collection U. S. National Museum.

1*a*. Enlargement of the outer surface to ten diameters. Collection U. S. National Museum.

1*b*. Longitudinal section of a specimen showing the vesiculose inner wall, which, when the outer wall and septa are broken away, gives the form described by Mr. Meek as *E. gracilis*. Collection U. S. National Museum.

1*c*. Transverse section showing the structure mentioned of Fig. 1*b* still more clearly ; also, the septa and poriferous outer wall; 37 septa. Collection U. S. National Museum.

1*d*. Transverse section, 1.5^{mm} in diameter, showing 8 septa. Collection U. S. National Museum.

1*e*. Similar section to 1*d*, with 14 septa.

ETHMOPHYLLUM MEEKI	601

FIG. 2. A large transverse section, with 58 septa ; numerous partitions between the septa, the outer poriferous wall, and the openings between the septa. Collection U. S. National Museum.

2*a*. A fragment showing the inner and outer walls, septa, dissepiments, outer surface with large pores, and the interior cup.

2*b*, 2*c*. Transverse section of a small specimen referred doubtfully to this species.

ETHMOPHYLLUM MARIANUS	601

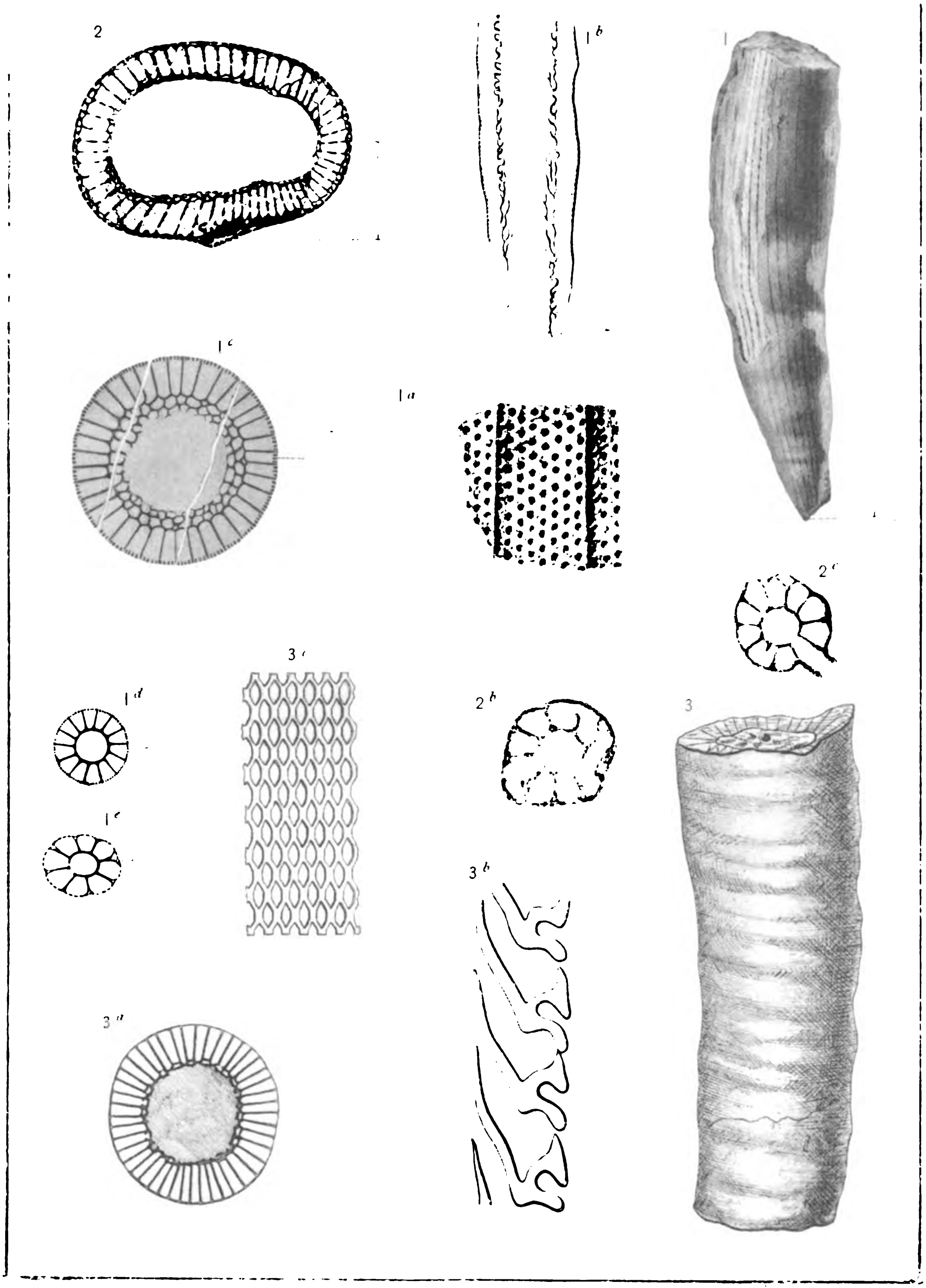
FIG. 3. Exterior view of a subcylindrical tube, showing the septa and interior wall at the apex. (After Roemer.)

3*a*. Transverse section. (After Roemer.)

3*b*. Enlargement of the plates on the inner wall that separate the openings into the wall pores. (After Roemer.)

3*c*. Enlargement of the poriferous surface. (After Roemer.)

See Pl. LIII.



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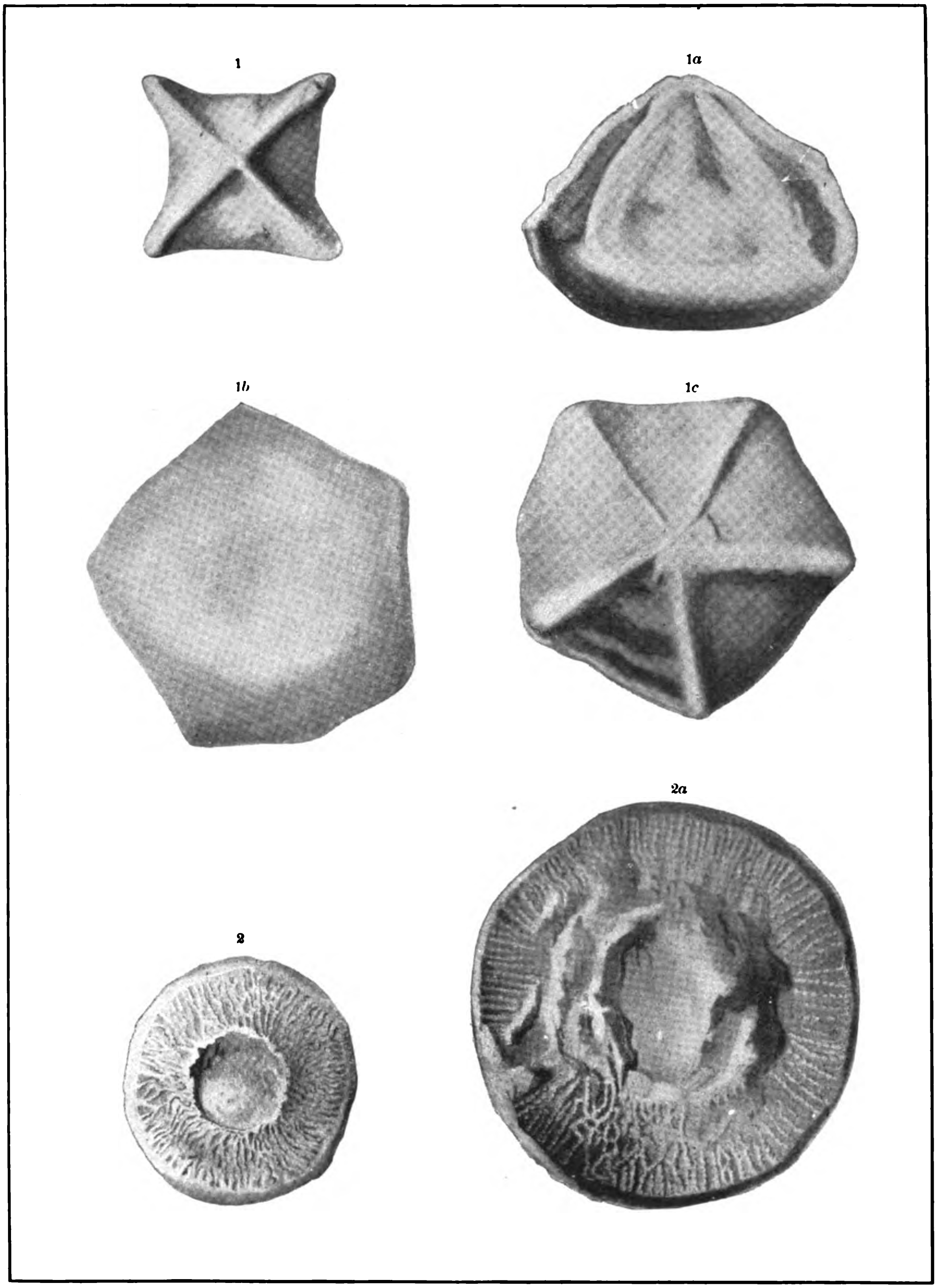
ACTINOZOA.

PLATE LVI.

Plate LVI.



HYDROZOA.

PLATE LVII.

PLATE LVII.

FIG. 1. Reproduction of a photograph of a portion of a slab of slate in the New York State Museum of Natural History.

A. A specimen showing six rays and a thick central portion.

B. An imperfect specimen similar to that shown by the original figure of the species by Dr. Fitch.

C. A specimen with five divisions of the type illustrated by Professor Hall.

D, E. Two specimens with apparently seven divisions.

The traces of annelid trails scattered over the surface were referred to *Fucoides flexuosa* by both Fitch and Hall.


d

OZOA.

PLATE LVIII.

Plate LVIII.

	Page.
Dactyloidites asteroides	607

Fig. 1. The five specimens represented on this plate illustrate the variation of 5, 6, and 7 rays, and the widest range in the character of the species yet observed. Dr. Fitch's type is of the form of the small individual in the upper corner, and Prof. Hall's is like that of the large upper one. These specimens are scattered over the surface of a large slab of slate now in the collections of the U. S. National Museum.

HYDROZOA.

PLATE LIX.

PLATE LIX.

Page.

FIG. 1. A problematical organic marking, from the Olenellus slates of Georgia, Vt.

EOPHYTON LINNÆANUM.. 587

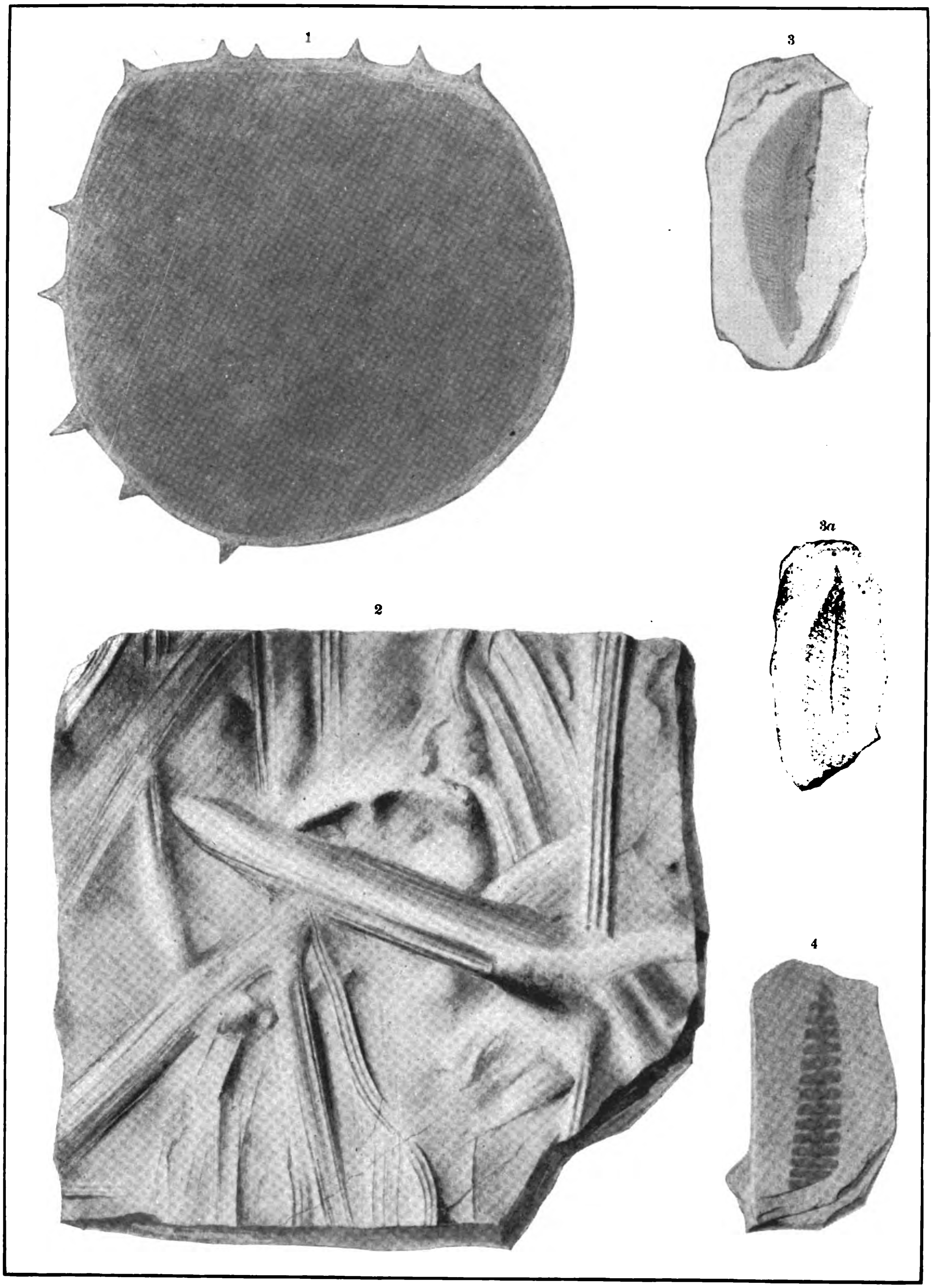
FIG. 2. Drawing of a specimen from Sweden. This marking is regarded as the trail made by a Medusa in passing over soft mud. By Nathorst.

PHYLLOGRAPTUS? CAMBRENSIS.. 604

FIG. 3, 3*a*. Two fronds, natural size, from the fine grained argillites of Parker's quarry. Collection U. S. National Museum.

CLIMACOGRAPTUS ?? EMMONSI.. 605

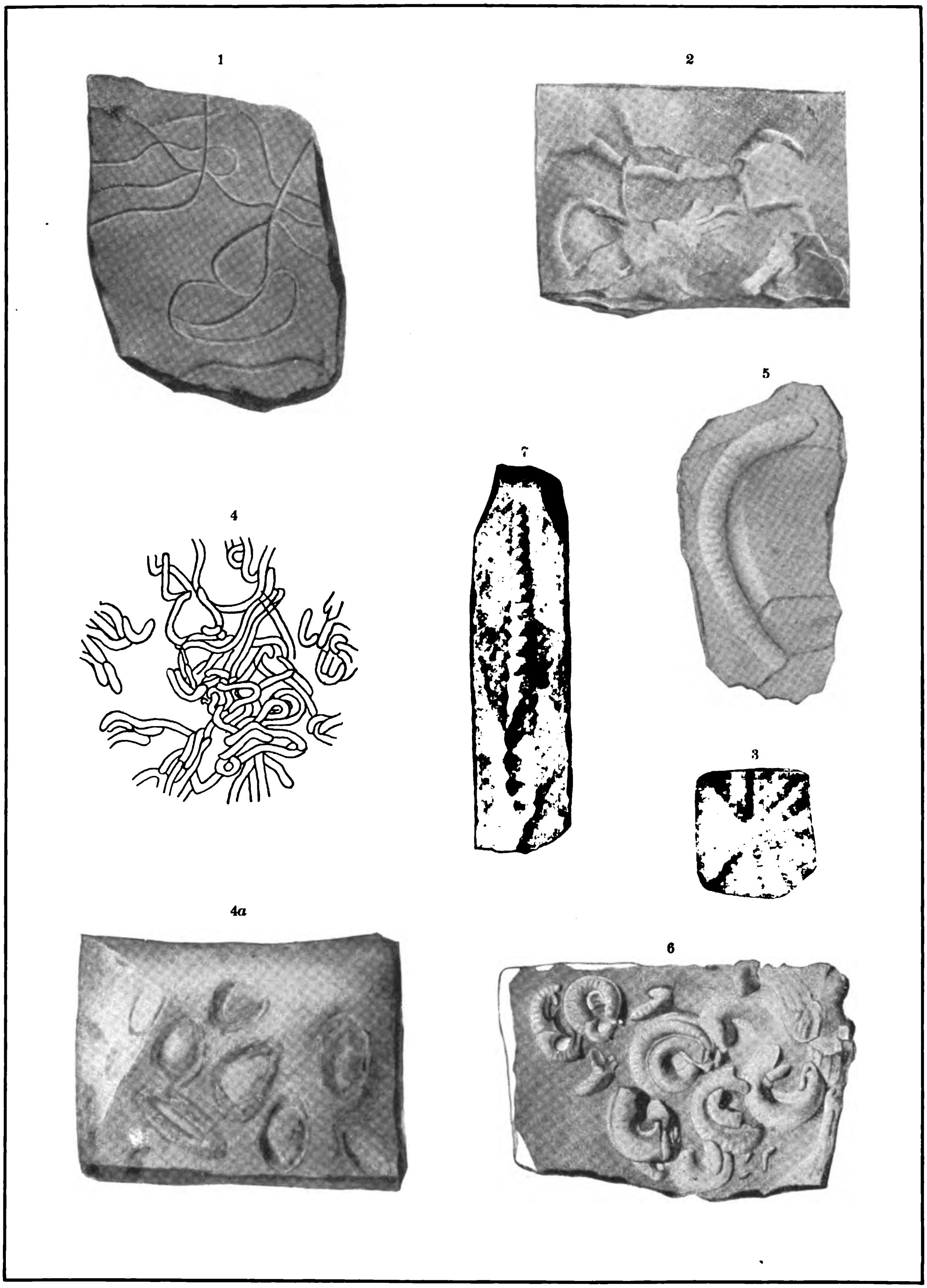
FIG. 4. A flattened stipe in the fine grained shales containing *Olenellus thompsoni*, at Parker's quarry, Georgia, Vt.



HYDROZOA.

PLATE LX.

Plate LX.



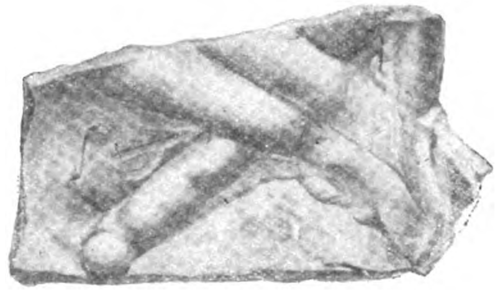
ECHINODERMATA. ANNELIDA.

PLATE LXI.

Plate LXI.

1

2



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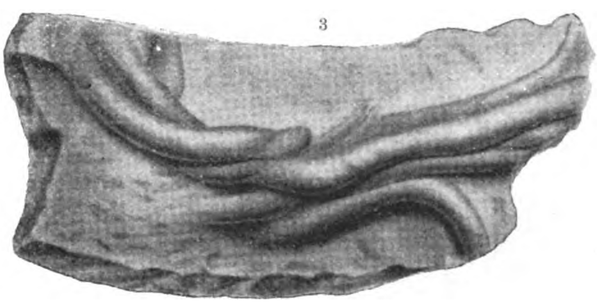


4

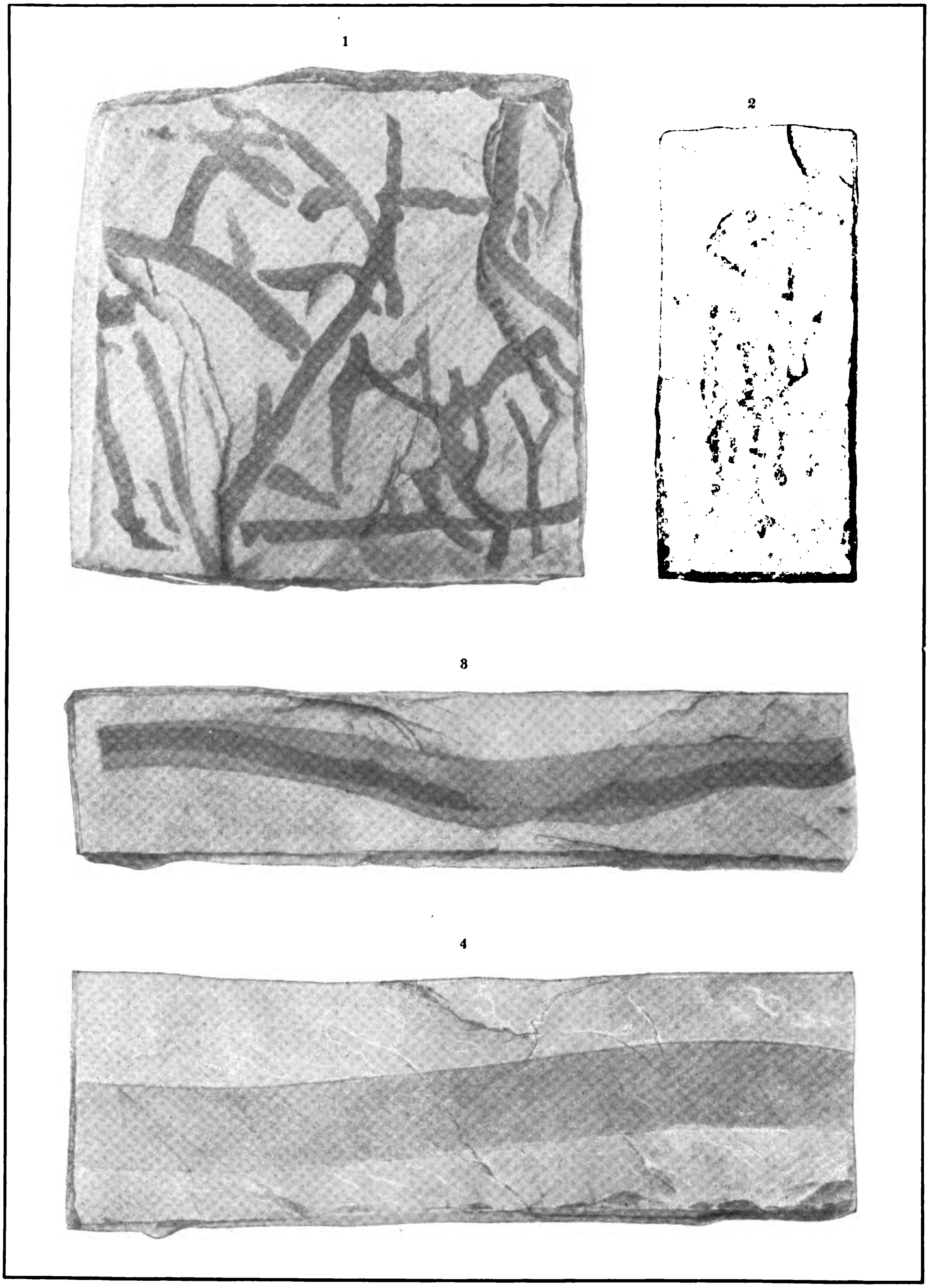
5

ANNELIDA.

PLATE LXII.

PLATE LXII.

FIGS. 1–4. The simple burrow or trail is shown by Figs. 3 and 4. In Figs. 1 and 2, numerous trails cross each other and give rise to what might be identified as a species of Paleophycus. All the specimens are crushed flat in the shale. The same species of worm may have made the burrows shown on Pls. LXI and LXII, the entire form being preserved in the first and only the flattened outline in the second plate.



ANNELIDA.

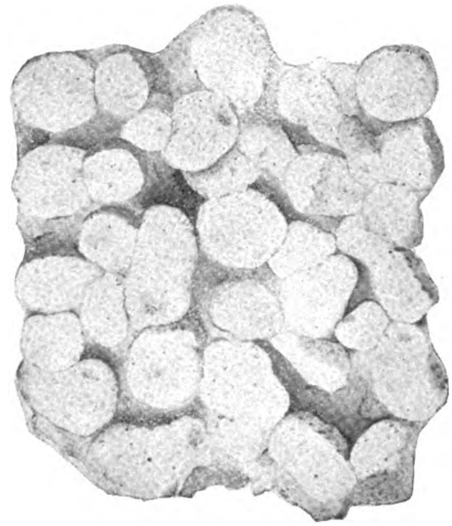
PLATE LXIII.

Plate LXIII.

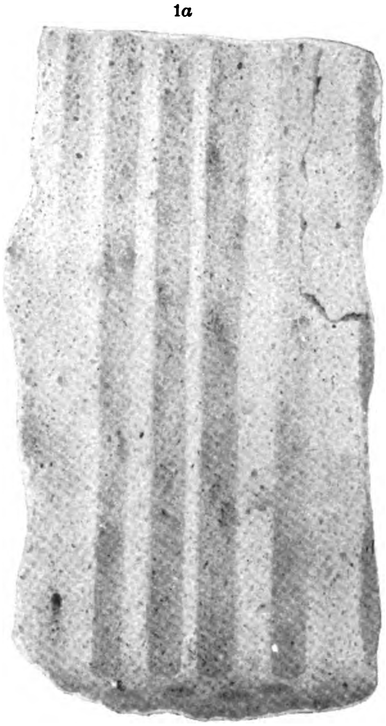
Fig. 1. The cast of a single tube preserved in a coarse sandstone.
1*a*. Tubes filled with sand of a darker color than the matrix.
1*b*. Tube leading to the surface of the layer of sandstone, where the cast of a cup-like depression occurs.
1*c*. Summit view of a group of casts of the cup-like depressions, shown by Fig. 1*b*.

1

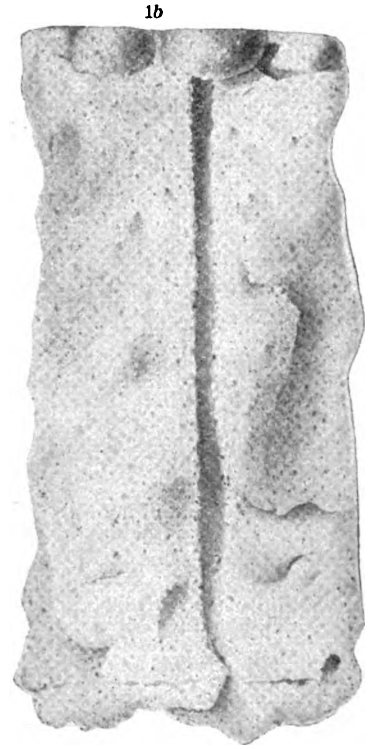
1c



1a



1b

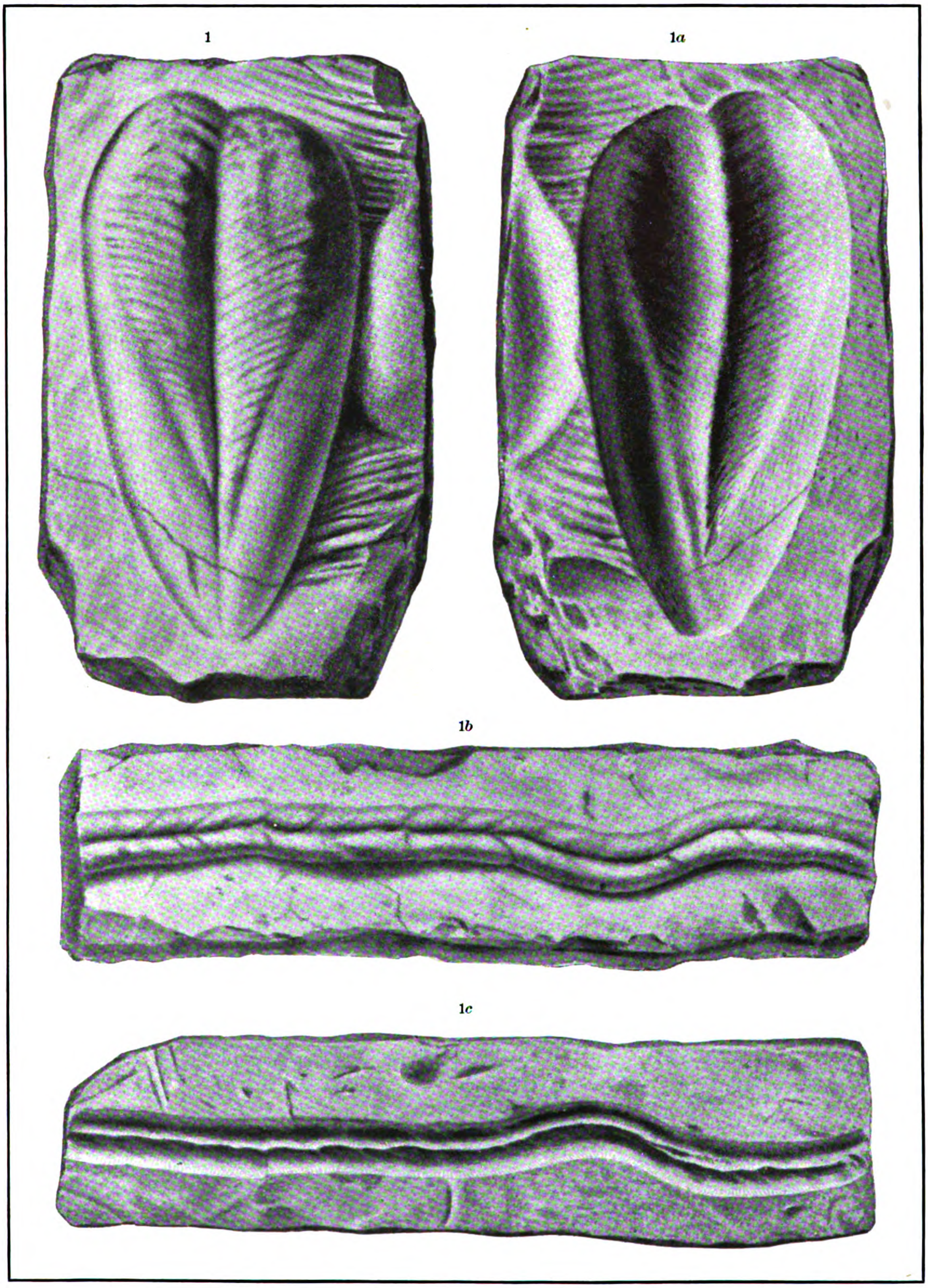


ANNELIDA.

PLATE LXIV.

PLATE LXIV.

FIG. 1. The cast of a single impression of the animal.
1*a*. Cast of Fig. 1, to show the lower surface impression left in the arenaceous mud by the animal.
1*b*. Cast of a narrow trail, in which the movement of the animal make a continuous furrow.
1*c*. Cast of 1*a*, to show the impression left by the animal.
See Pls. LXV and LXVI.



CRUSTACEA?

PLATE LXV.

PLATE LXV.

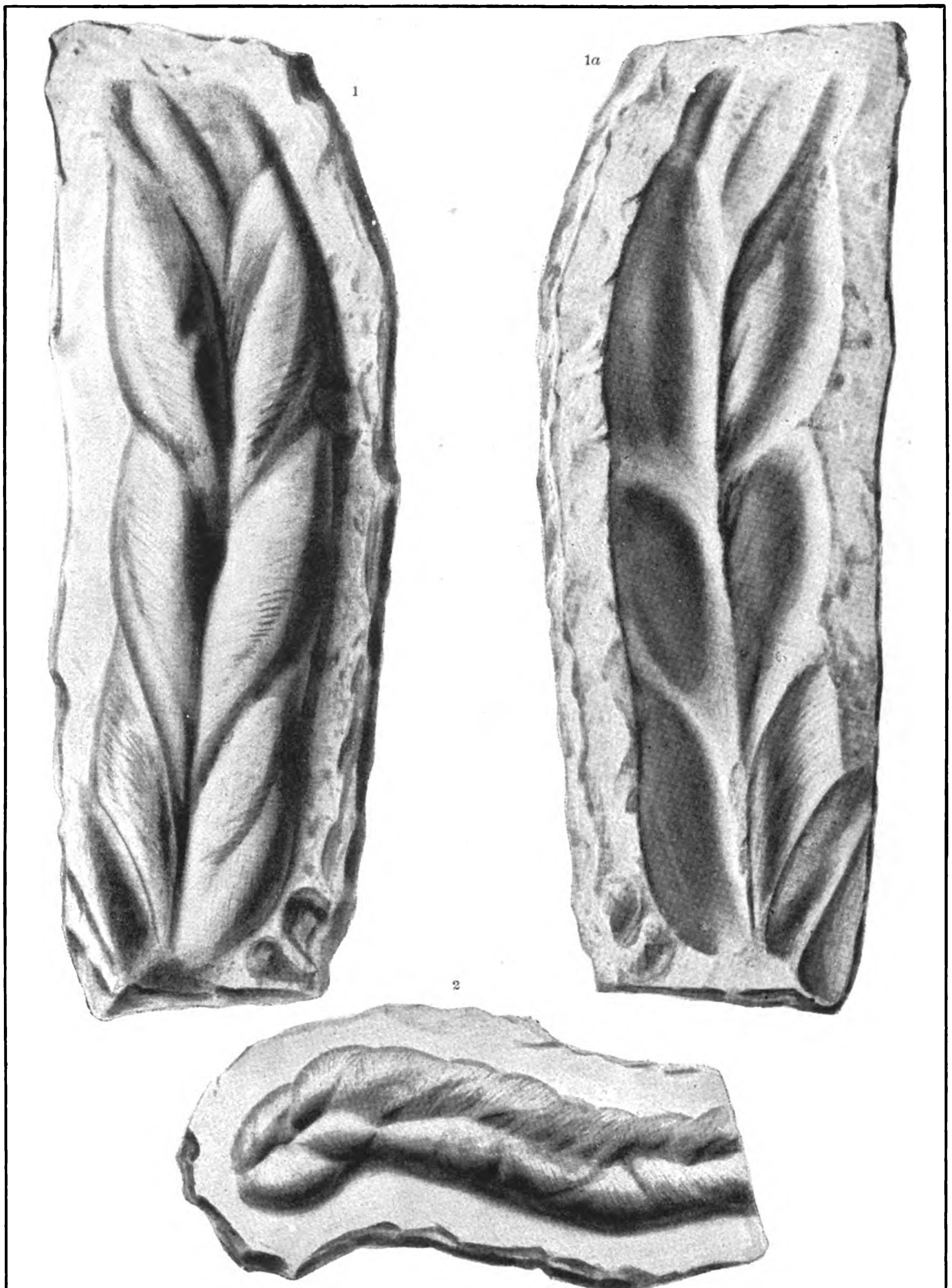
	Page.
CRUZIANA, sp.?	604

FIG. 1. The cast of a number of impressions, such as are represented by Fig. 1, Pl. LXIV.

1*a*. Cast of 1, to show the impression left by the animal in its successive movements. In Fig. 1c, Pl. LXIV, the single impressions are nearly lost sight of.

2. Cast of a number of impressions in which the individual impressions are merged more into each other than in Fig. 1.

See Pls. LXIV and LXVI.



CRUSTACEA?

PLATE LXVI.

PLATE LXVI.

CRUSTACEA ?

PLATE LXVII.

Plate LXVII.

Page.

Lingulella cælata 607

Fig. 1. Ventral valve, enlarged to 2 diameters. Collection S. W. Ford.

1*a*. Side view of same, with a view of the beak, looking from behind.

1*b*. Enlargement of a small dorsal (?) valve. Collection U. S. National Museum.

1*c*. Dorsal valve, enlarged. Collection U. S. National Museum.

1*d*. Surface of dorsal valve, greatly enlarged.

1*e*. Cast of the interior of a dorsal valve. Collection U. S. National Museum.

Lingulella ella.. 607

Fig. 2. Ventral valve, showing the area, deltidial opening, and cast of the exterior surface of the valve; enlarged. Collection U. S. National Museum.

2*a*. Cast of the interior of the dorsal valve, showing the position of the muscular scars. Collection U. S. National Museum.

2*b*. View of the type specimen, enlarged to two diameters. Collection U. S. National Museum.

2*c*. Cast of the interior of a very small ventral valve, enlarged six diameters. Collection U. S. National Museum.

2*d*. Cast of the interior of a very small dorsal valve, enlarged six diameters. Collection U. S. National Museum.

2*e*. Enlargement of the surface of a specimen from the shales at the Chisholm mine. Collection U. S. National Museum.

Lingulella ? sp. ?.. 698

Fig. 3. A single valve found in association with *Olenellus asaphoides*, in Washington County, N. Y. Collection U. S. National Museum.

Lingulella granvillensis 607

Fig. 4. Dorsal valve preserving portions of the outer shell. Collection U. S. National Museum.

4*a*. Cast of the interior of a dorsal valve, showing muscular scars and vascular markings. CollectionU. S. National Museum.

4*b*, 4*c*. Ventral valves, showing elongate muscular scars and fragments of the outer shell. Collection U. S. National Museum.

4*d*. A ventral valve, doubtfully referred to this species. Collection U. S. National Museum.

Acrotreta gemma 608

Fig. 5. View of the posterior side of the ventral valve, enlarged to six diameters. Collection U. S. National Museum.

5*a*. Cast of the interior of the apex of the ventral valve, showing a cast of the siphonal tubes and the elongate muscular scars, enlarged to six diameters. Collection U. S. National Museum.

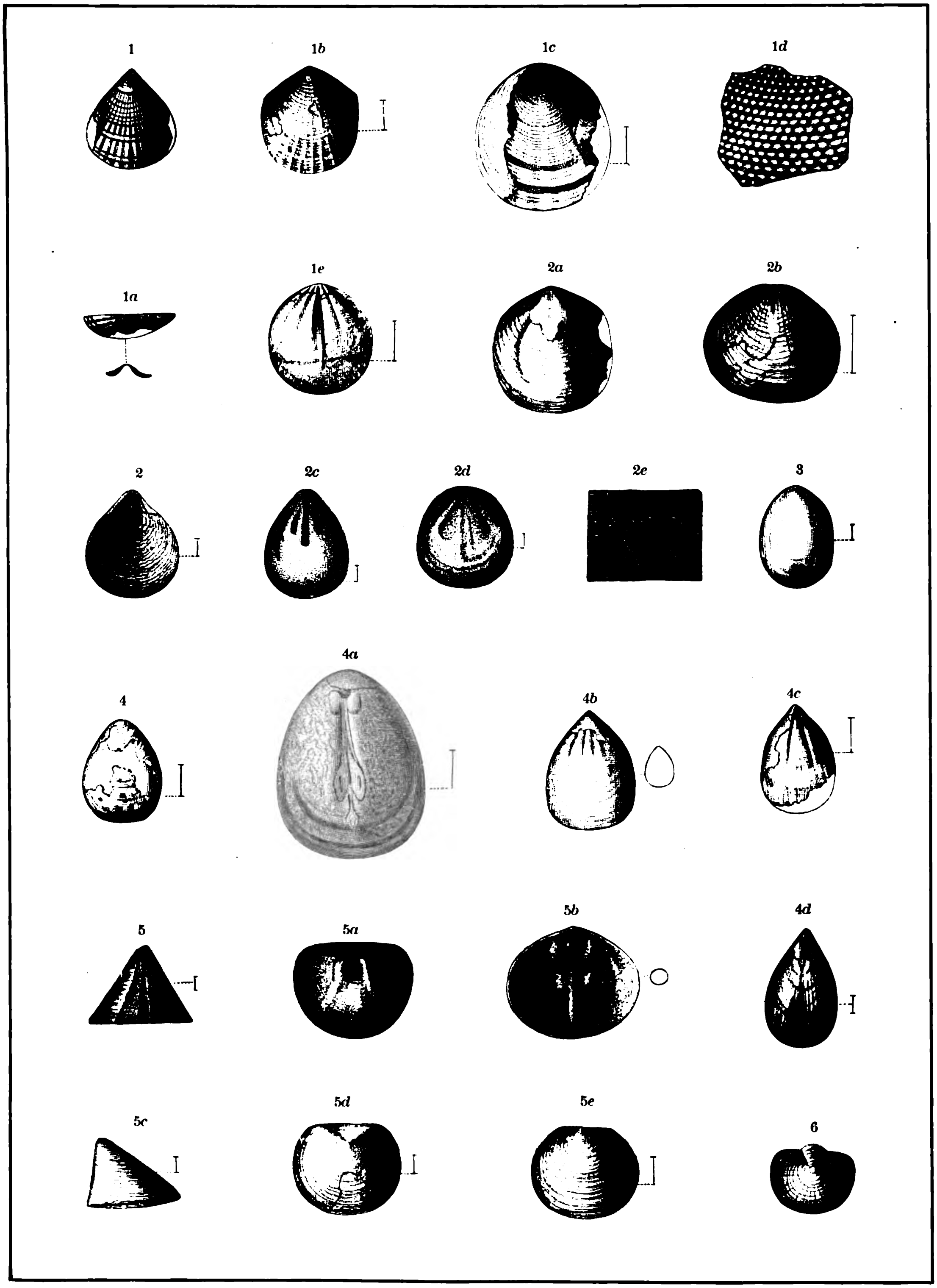
5*b*. Interior of ventral valve, enlarged to six diameters. Collection U. S. National Museum.

5*c*, 5*d*. Summit and side views of the dorsal valve, enlarged to three diameters. Collection U. S. National Museum.

5*e*. Ventral valve, enlarged to three diameters. Collection U. S. National Museum.

Iphidea bella 608

Fig. 6. Copy of the original figure given by Mr. Billings. Ventral (?) valve. Collection Geological Survey, Canada.



BRACHIOPODA.

PLATE LXVIII.

PLATE LXVIII.

FIG. 1. Ventral valve, enlarged.

1*a*. Cast of the interior of a dorsal valve.

1*b*. Dorsal valve.

1*c*. Cast of the interior of a ventral valve.

1*d*. Interior of ventral valve. Collection U. S. National Museum.

FIG. 2. Exterior of the ventral valve, greatly enlarged.

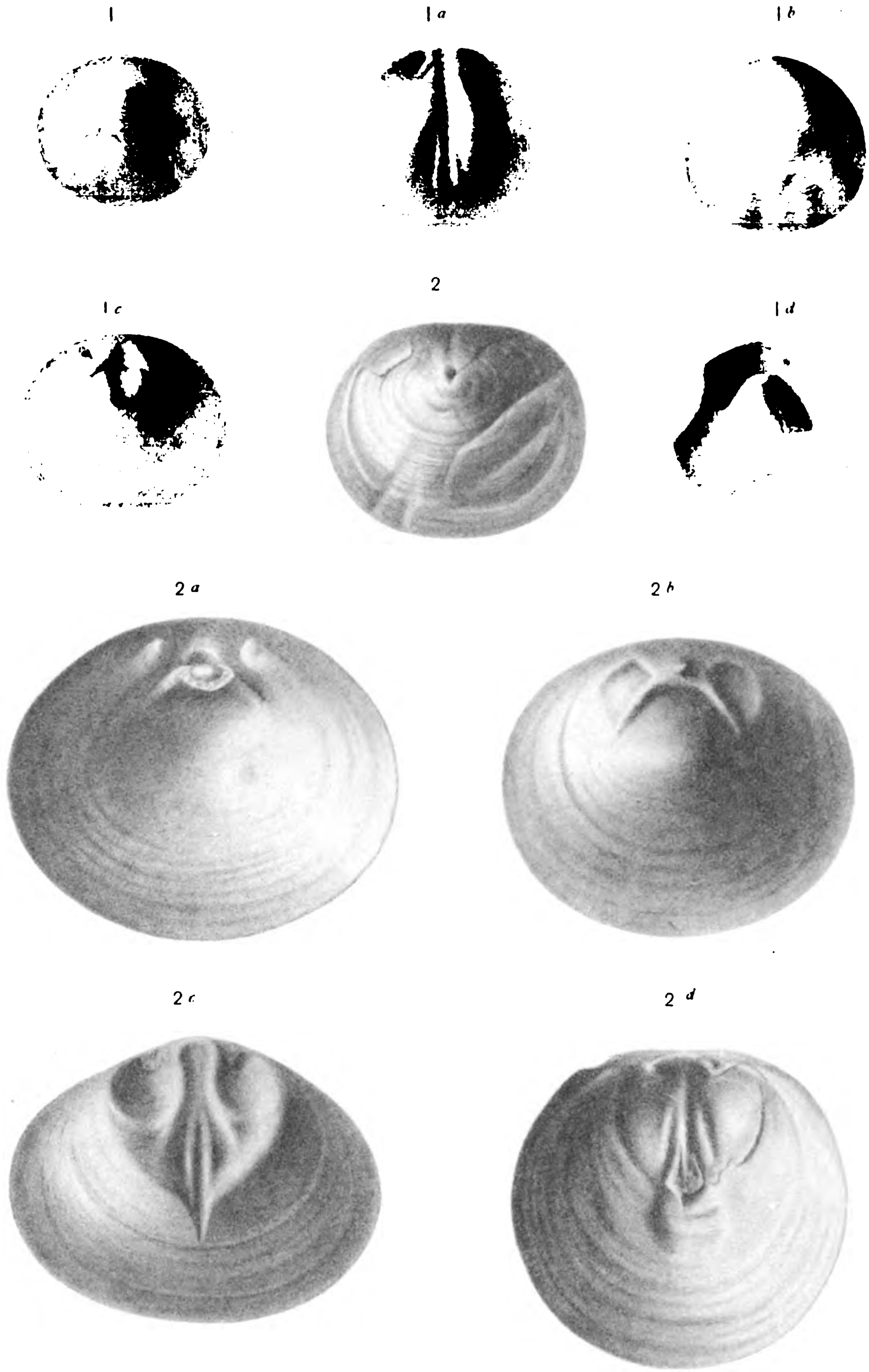
2*a*. Interior of the ventral valve of the variety *transversa*, from St. John, New Brunswick.

2*b*. Cast of the interior of the ventral valve.

2*c*. Cast of the interior of the dorsal valve of the variety *transversa*, from St. John, New Brunswick.

2*d*. Interior of the dorsal valve of the variety *transversa*, from St. John, New Brunswick.

These figures are inserted for comparison with Figs. 1–1*d*, and to illustrate the characters of the genus.



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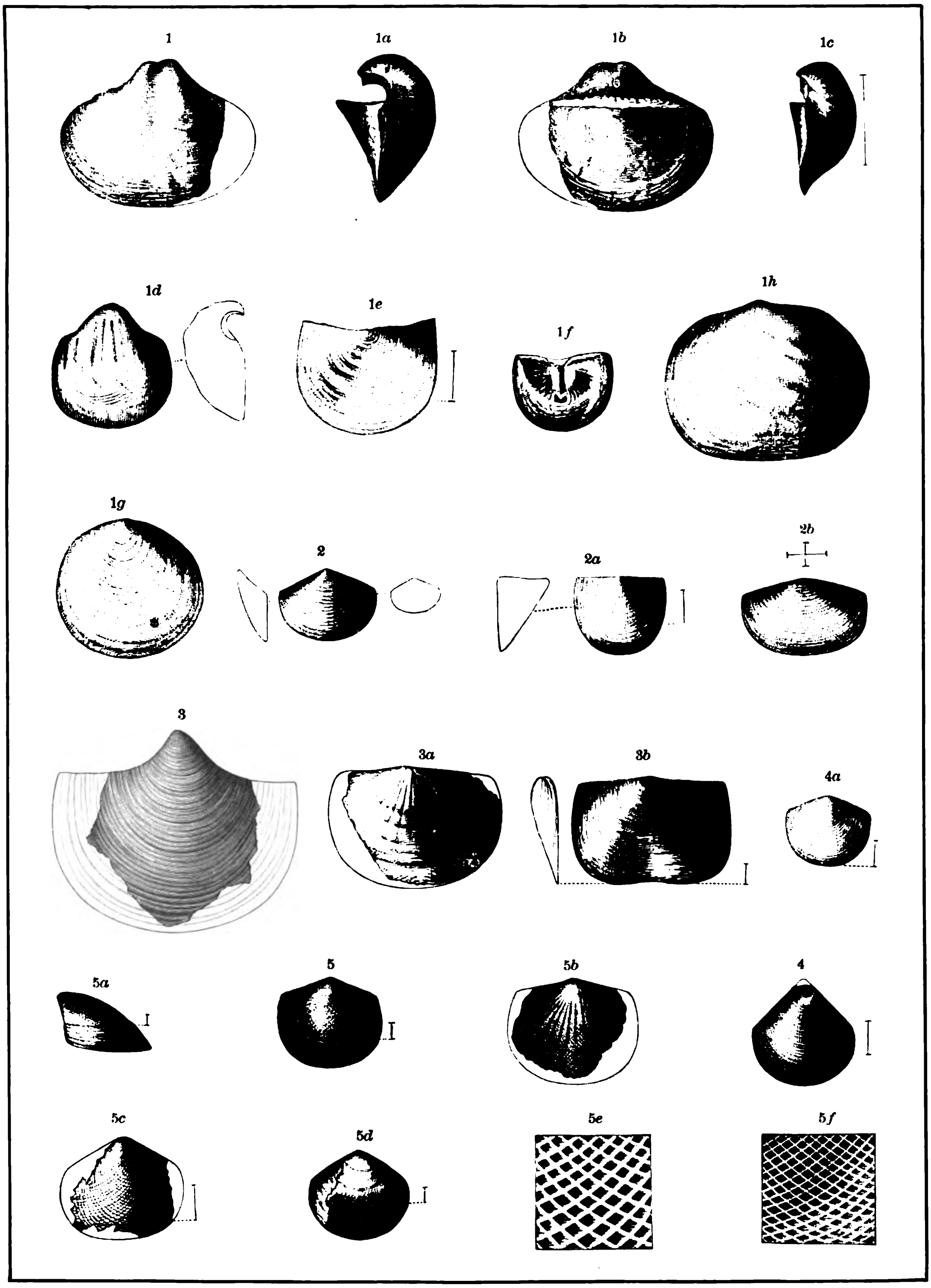
BRACHIOPODA.

PLATE LXIX.

PLATE LXIX.



BRACHIOPODA.

PLATE LXX.

Plate LXX.

	Page
Acrothele subsidua	608

Fig. 1. Ventral valve, from Pioche, Nevada, showing exterior surface, enlarged. Collection U. S. National Museum.

1*a*. Interior of dorsal valve, enlarged. Collection U. S. National Museum.

1*b*. Ventral valve, from Antelope Spring, Utah, with exterior surface removed, enlarged. Collection U. S. National Museum.

1*c*. Cast of interior of dorsal valve, enlarged. Collection U. S. National Museum.

Mickwitzia monolifera	704

Fig. 2. Interior of flat valve. (After Schmidt.)

2*a*. Side view to show the form of the large tooth. (After Schmidt.)

2*b*. Exterior view of flat valve. (After Schmidt.)

2*c*. Interior of convex valve, showing a deep depression in the shell. (After Schmidt.)

2*d*. Anterior view, showing an oblique triangular area. (After Schmidt.)

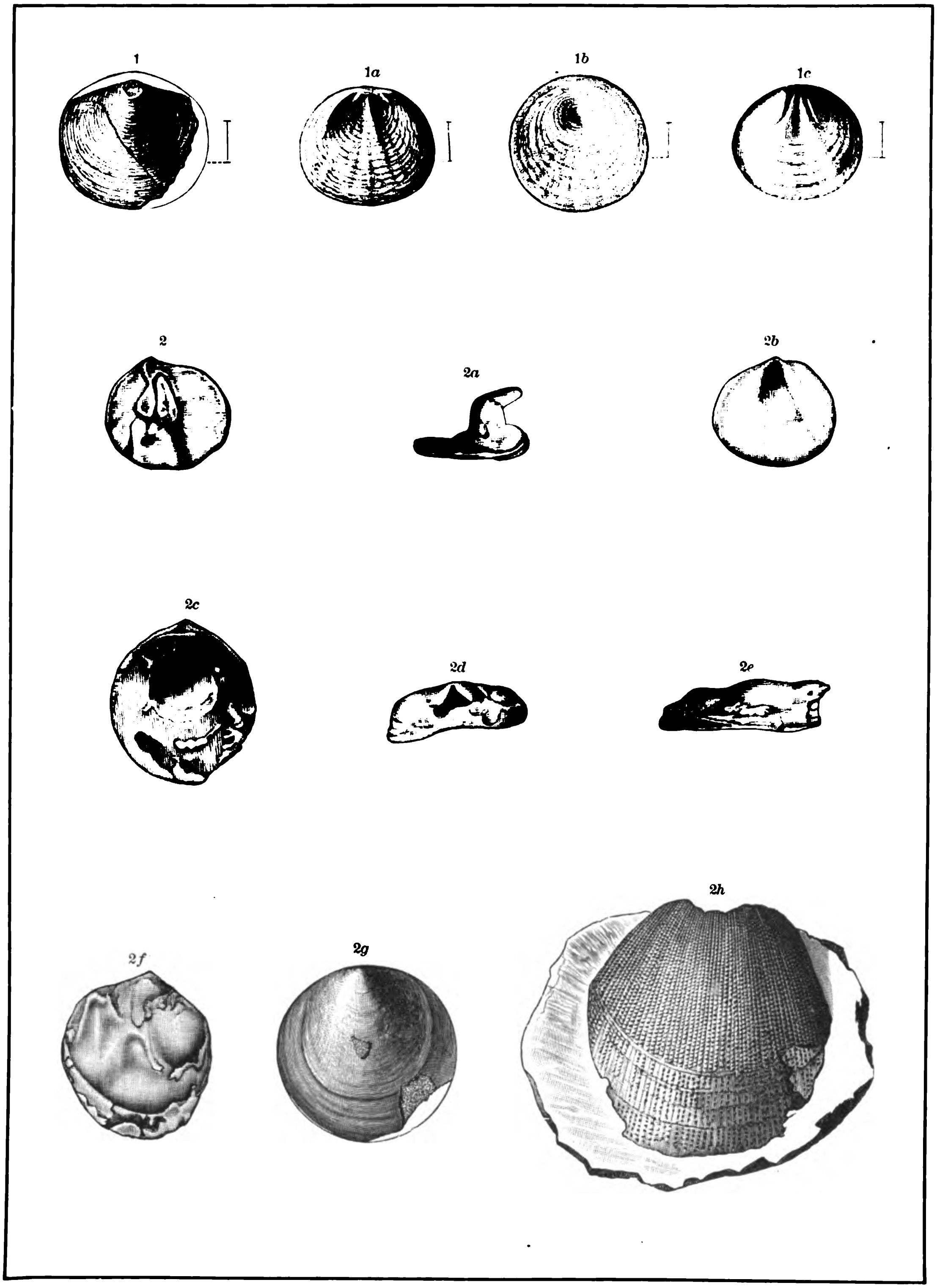
2*e*. Side view, showing projecting beak. (After Schmidt.)

2*f*. Exterior view of convex valve. (After Schmidt,)

2*g*. Exterior view of a ventral (?) valve, from the Lugnas sandstone of Sweden. Collection U. S. National Museum.

2*h*. Outer surface of the shell, enlarged. (After Linnarsson.)

All of the views taken from Dr. Schmidt's work appear to have been drawn from casts of the shell. "Ueber eine neuentdeckte untercambrische Fauna in Estland." Mém. Acad. Imp. Sci. St. Pétersbourg, VIII, vol. 36, N. 2, 1888, pp. 1–27, Pls. i, ii.

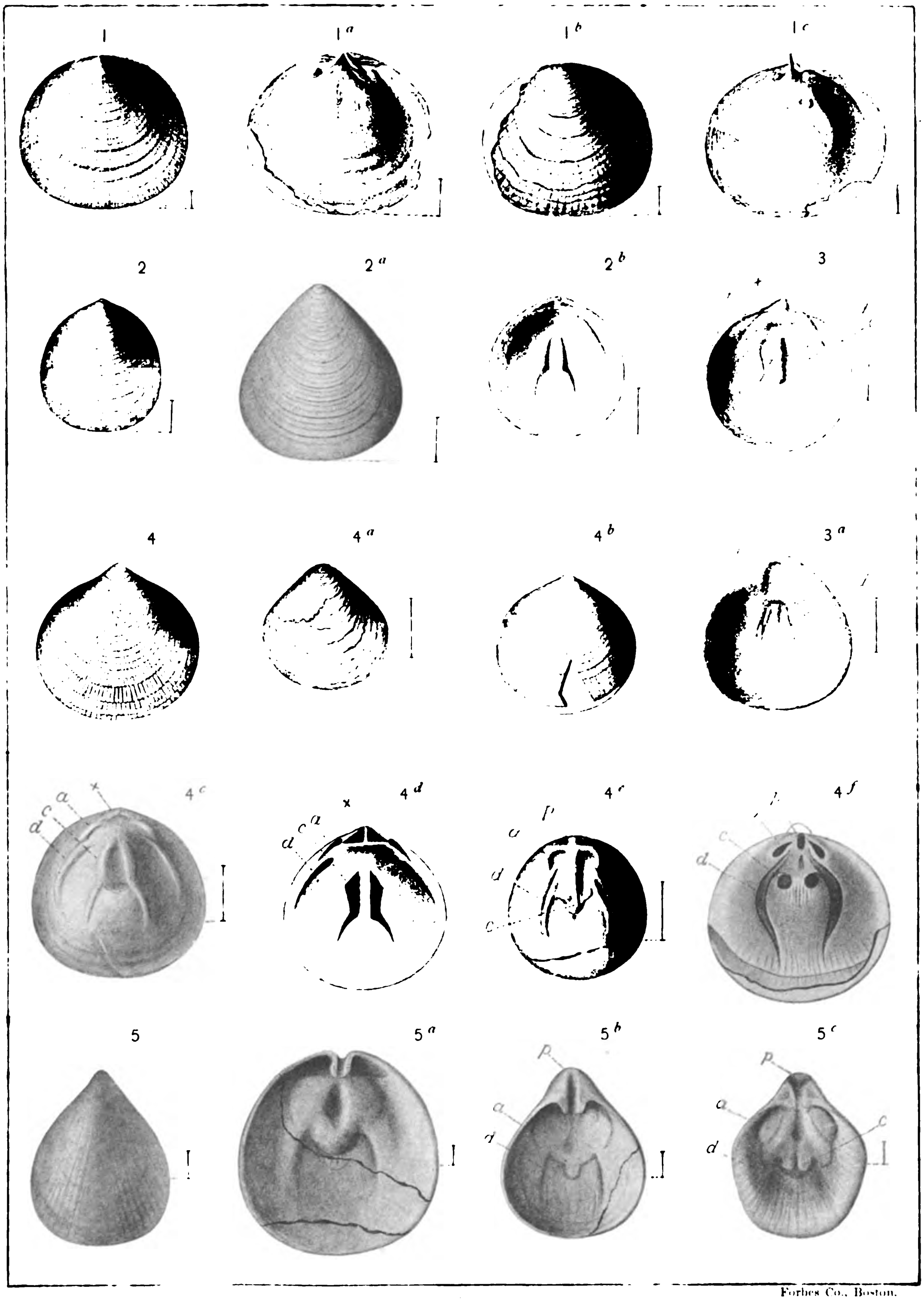


BRACHIOPODA.

PLATE LXXI.

Plate LXXI.

See Figs. 2 and 2*a*, Pl. LXXII.



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BRACHIOPODA.

PLATE LXXII.

707

Plate LXXII.

	Page.
Obolella nitida	612

Fig. 1. Dorsal ? valve, enlarged to five diameters. Collection U. S. National Museum.

Obolella gemma	612

Fig. 2. Ventral valve, from Troy, N. Y., enlarged to six diameters. Collection S. W. Ford.

2*a*. Exterior of dorsal valve, from Troy, N. Y. Collection U. S. National Museum.

See Pl. LXXI, Figs. 5, 5*a*–5*c*.

Camarella ? antiquata	613

Fig. 3. Ventral valve, enlarged. Collection U. S. National Museum.

Camarella minor	614

Fig. 4, 4*d*. Casts of ventral valves. Collection U. S. National Museum.

4*a*. Exterior of ventral valve. Collection U. S. National Museum.

4*b*. Exterior of dorsal valve.

4*c*. Cast of interior of dorsal valve.

Orthis ? highlandensis	612

Fig. 5. Dorsal valve, with most of the exterior shell worn away. Collection U. S. National Museum.

5*a*. Cast of the interior of the ventral valve. Collection U. S. National Museum.

5*b*. Exterior of the ventral valve, with the side restored from another specimen. Collection U. S. National Museum.

Orthis salemensis	612

Fig. 6. Ventral valve and outline of its convexity.

6*a*. Dorsal valve.

Orthisina festinata	613

Fig. 7. Dorsal (?) valve, enlarged. Collection U. S. National Museum.

7*a*. View of area of 7.

7*b*. Ventral (?) valve and outline, natural size. Collection U. S. National Museum.

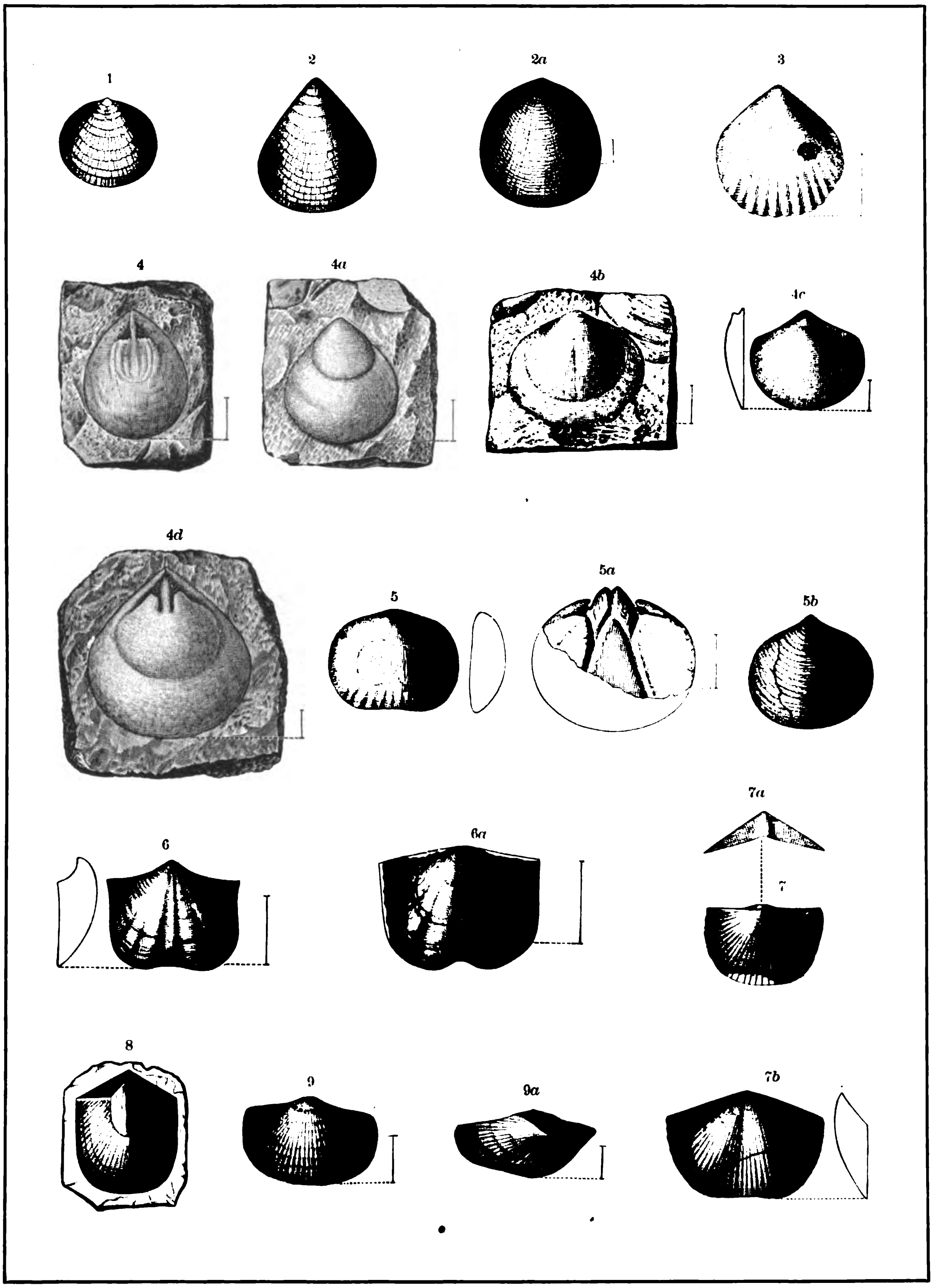
Orthisina orientalis	613

Fig. 8. Ventral valve, natural size. (After Whitfield.) Collection American Museum Natural History, New York City.

Orthisina transversa	613

Fig. 9. Ventral valve, enlarged two diameters. Collection U. S. National Museum.

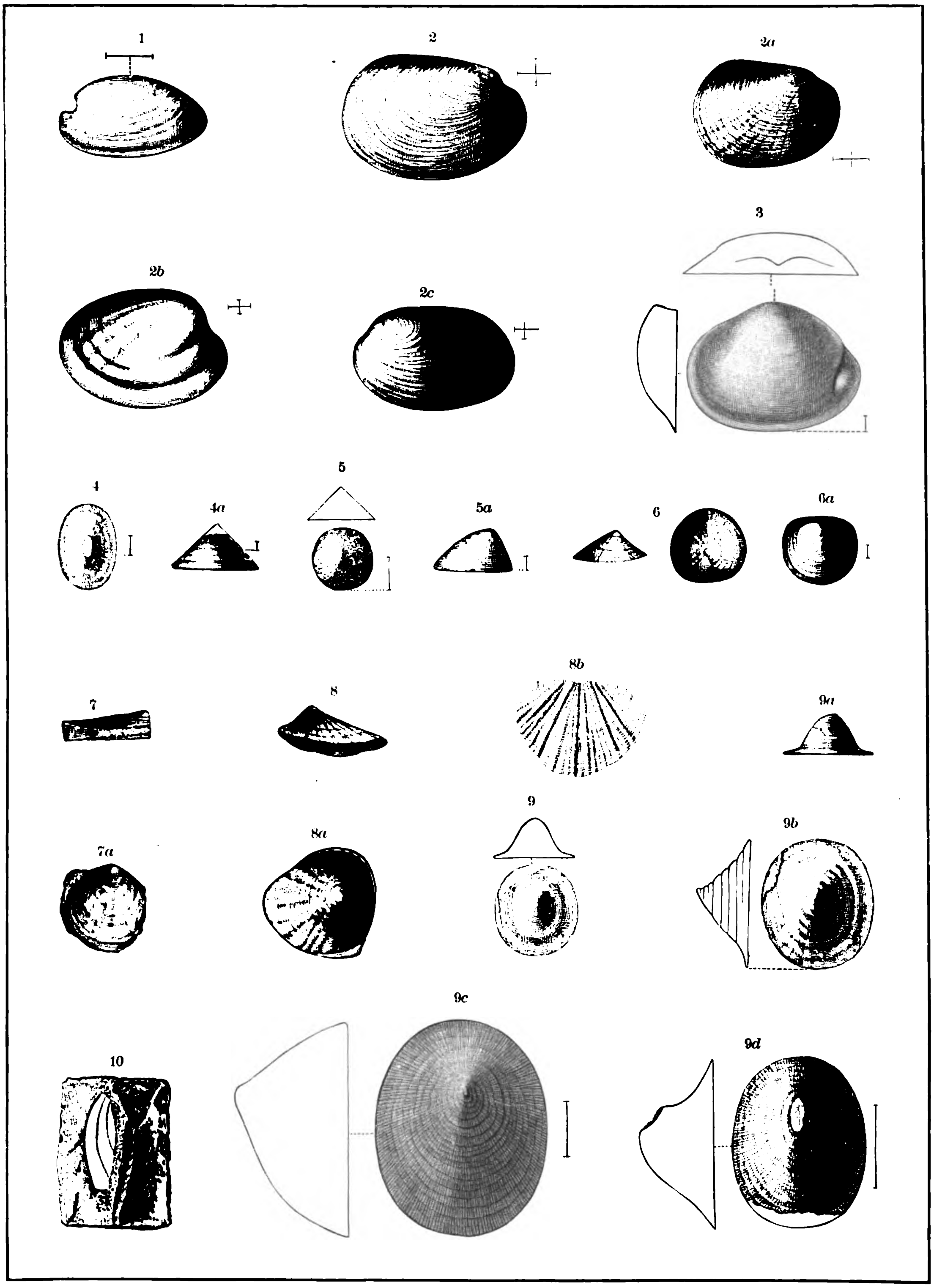
9*a*. Another specimen, showing the area. Collection U. S. National Museum.



BRACHIOPODA.

PLATE LXXIII.

PLATE LXXIII.



LAMELLIBRANCHIATA AND GASTROPODA.

PLATE LXXIV.

PLATE LXXIV.

Page.

STENOTHECA RUGOSA 617

FIG. 1. Lateral view of a medium sized specimen. Collection U. S. National Museum.

1a. Lateral view of a more elevated and coarsely annulated specimen than 1. Collection U. S. National Museum.

1b, 1c. Summit views of two specimens, to show eccentricity of apex. Collection U. S. National Museum.

1d. Side view of a shell from Conception Bay, Newfoundland. Collection U. S. National Museum.

1e. Side view of a shell from Washington County, N. Y. Collection U. S. National Museum.

1f. Enlargement of surface of shell represented by Fig. 1e.

1g. Variety, with finer annulations than 1e. From Washington County, N. Y.

1h, 1i. Side and summit views of a very small shell from Troy, N. Y.

STENOTHECA RUGOSA var. ACUTA-COSTA 617

FIG. 2. Side view, enlarged. Collection U. S. National Museum.

2a. Cast of the outer surface of a specimen, lying near the one represented by Fig. 2.

2b. Summit view of a compressed specimen with a campanulate margin. Collection U. S. National Museum.

STENOTHECA RUGOSA var. PAUPERA 617

FIG. 3. Side view of a specimen from Manuel's Brook, Conception Bay, Newfoundland. Collection U. S. National Museum.

7. Shaler & Foerste's figure of this variety.

STENOTHECA RUGOSA var. ERECTA 617

FIG. 4. Side view of type specimen, from Conception Bay, Newfoundland.

STENOTHECA RUGOSA var. LEVIS 617

FIG. 5. Side view of a specimen having three strong ridges. Collection U. S. National Museum.

5a. A nearly smooth specimen, from the same locality as the shell represented by Fig. 5; Conception Bay, Newfoundland. Collection U. S. National Museum.

STENOTHECA RUGOSA var. ABRUPTA 617

FIG. 6. An average size specimen. (After Shaler & Foerste.)

6a. Side view of a large specimen. (After Shaler & Foerste.)

STENOTHECA, sp. undetermined 712

FIG. 8. A small portion of a shell found in the hard limestones of Washington County, N. Y. Collection U. S. National Museum.

STENOTHECA ELONGATA 617

FIG. 9, 9a. Summit and lateral views of specimen from the Eureka district, Nevada. Collection, U. S. National Museum.

9b. Summit view of specimen from l'Anse au Loup. Collection U. S. National Museum.

STENOTHECA CURVIROSTRA 618

FIG. 10. Drawing made from a gutta-percha cast, taken in the matrix of the type specimen.

PLATYCERAS PRIMÆVUM 618

FIG. 11. View of cast, right side. Collection U. S. National Museum.

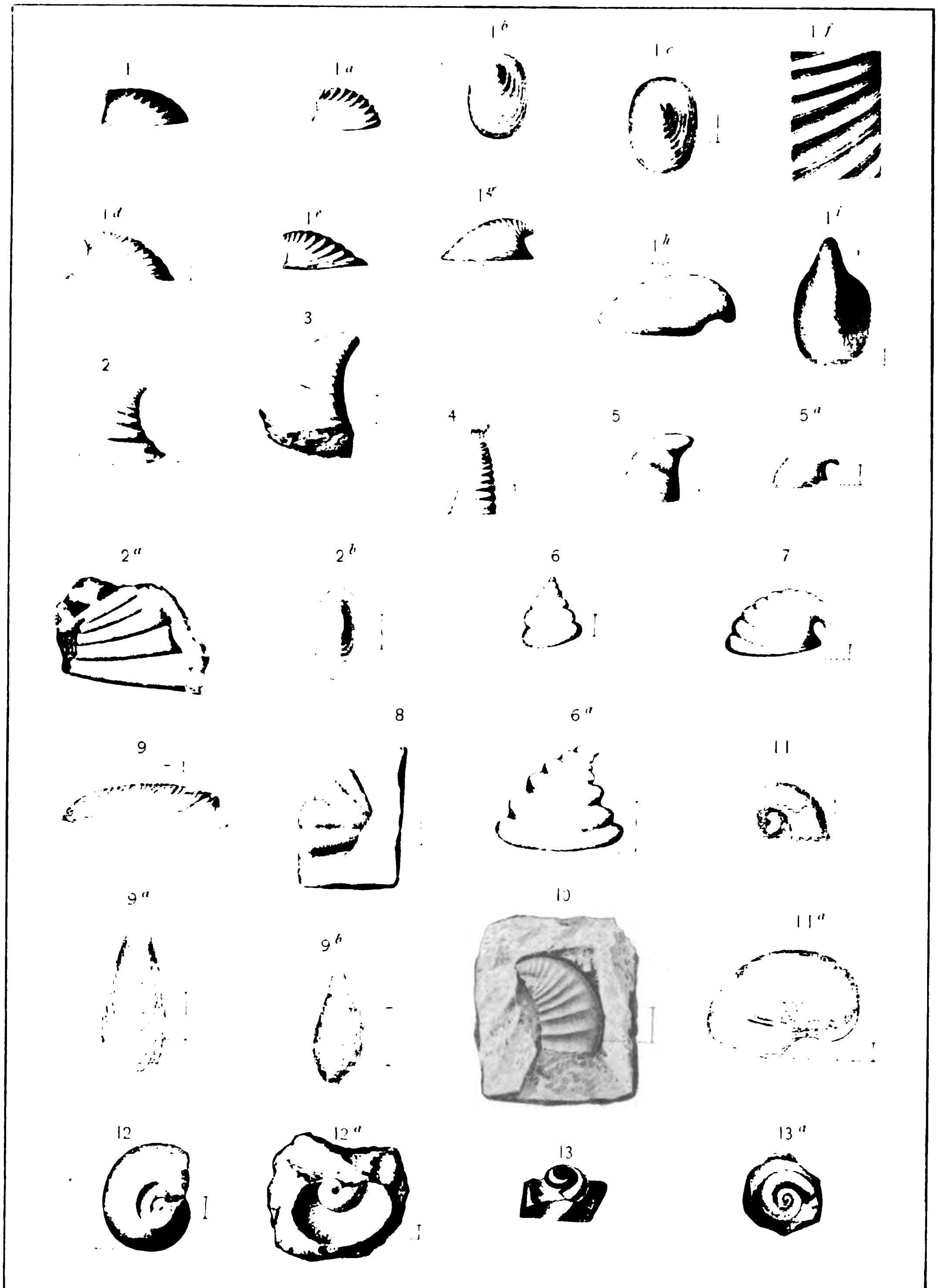
11a. Left side, enlarged to show characters of the outer surface of the shell. Collection U. S. National Museum.

PLEUROTOMARIA (R.) ATTLEBORENSIS 619

FIG. 12, 12a. Views of the type specimen. Collection Prof. N. S. Shaler.

STRAPAROLLINA REMOTA 619

FIG. 13, 13a. Summit and side views. (After Billings.)



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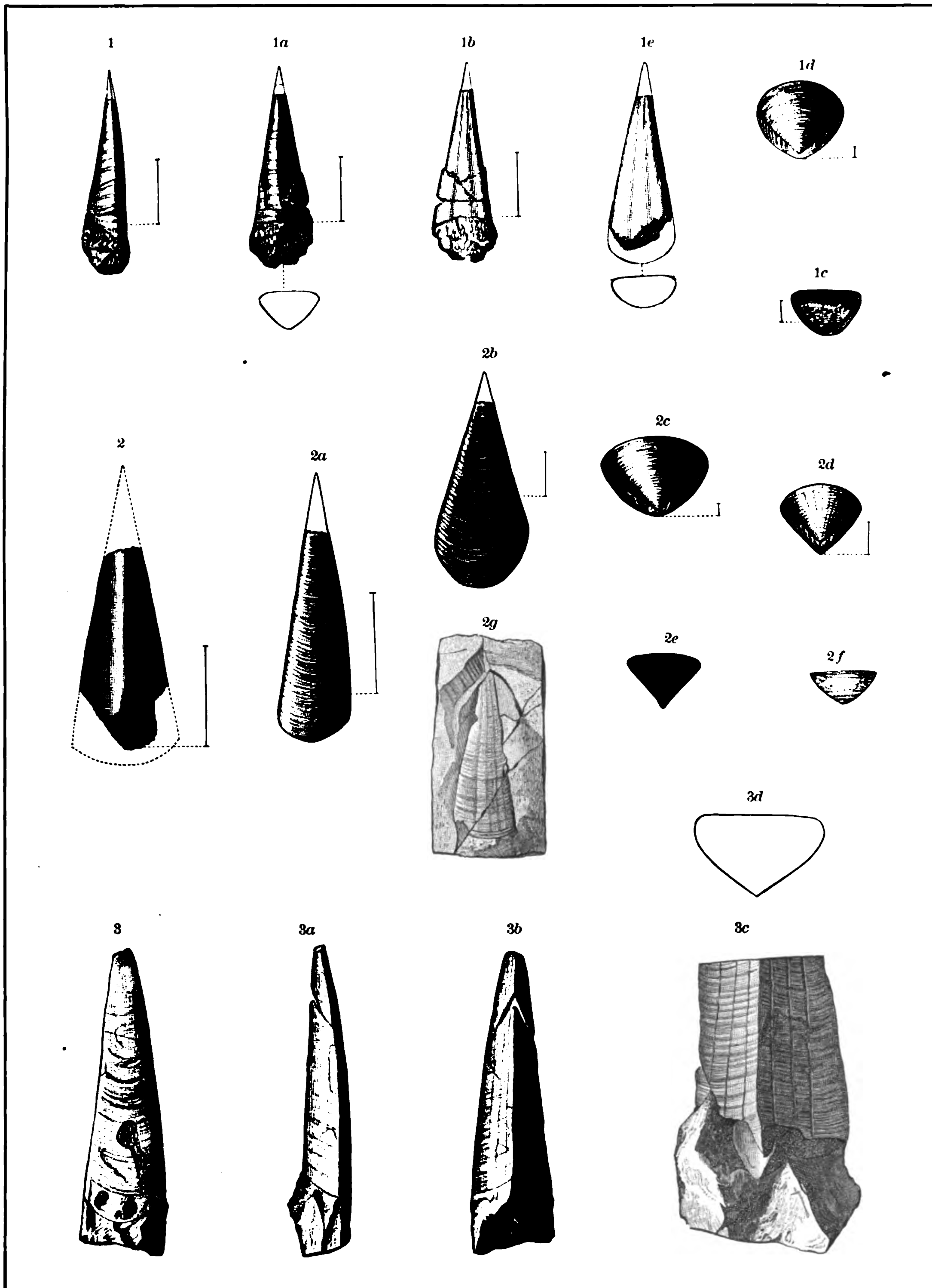
GASTEROPODA.

PLATE LXXV.

Plate LXXV.



PTEROPODA.

PLATE LXXVI.

Plate LXXVI.

Fig. 1, 1*a*, 1*b*. Dorsal, ventral, and lateral views of a very perfect medium size shell. Collection U. S. National Museum.

1*c*. Transverse section of 1.

1*d*. Transverse section of 1*e*.

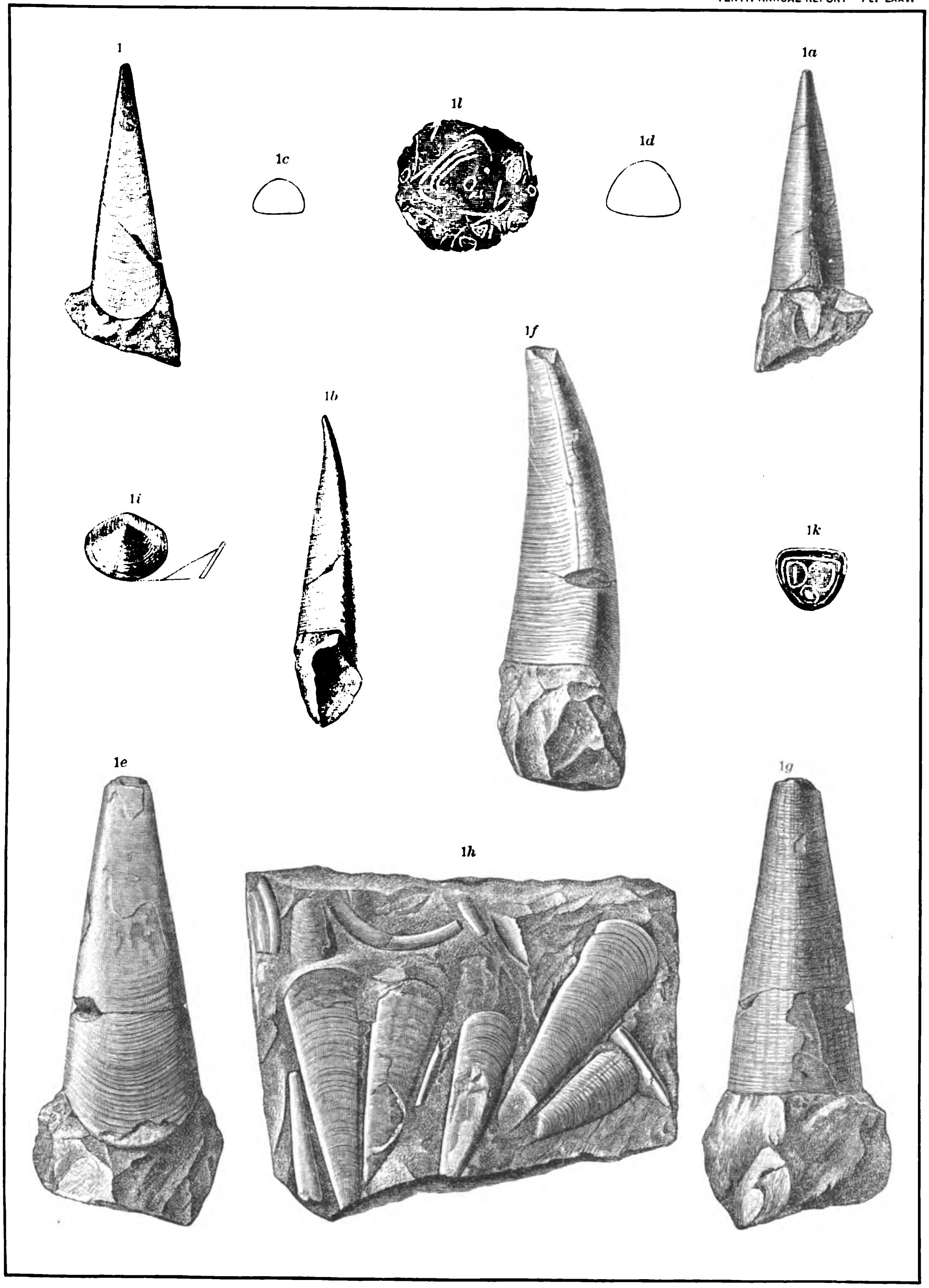
1*e*, 1*f*, 1*g*. Dorsal, lateral, and ventral views of a large shell. Collection U. S. National Museum.

1*h*. A group of shells lying on a slab of rock. Collection U. S. National Museum.

1*i*. Operculum associated with this species.

1*k*. Transverse section of a shell containing transverse sections of *Hyolithes quadricostatus* and *Helenia bella* inside of it.

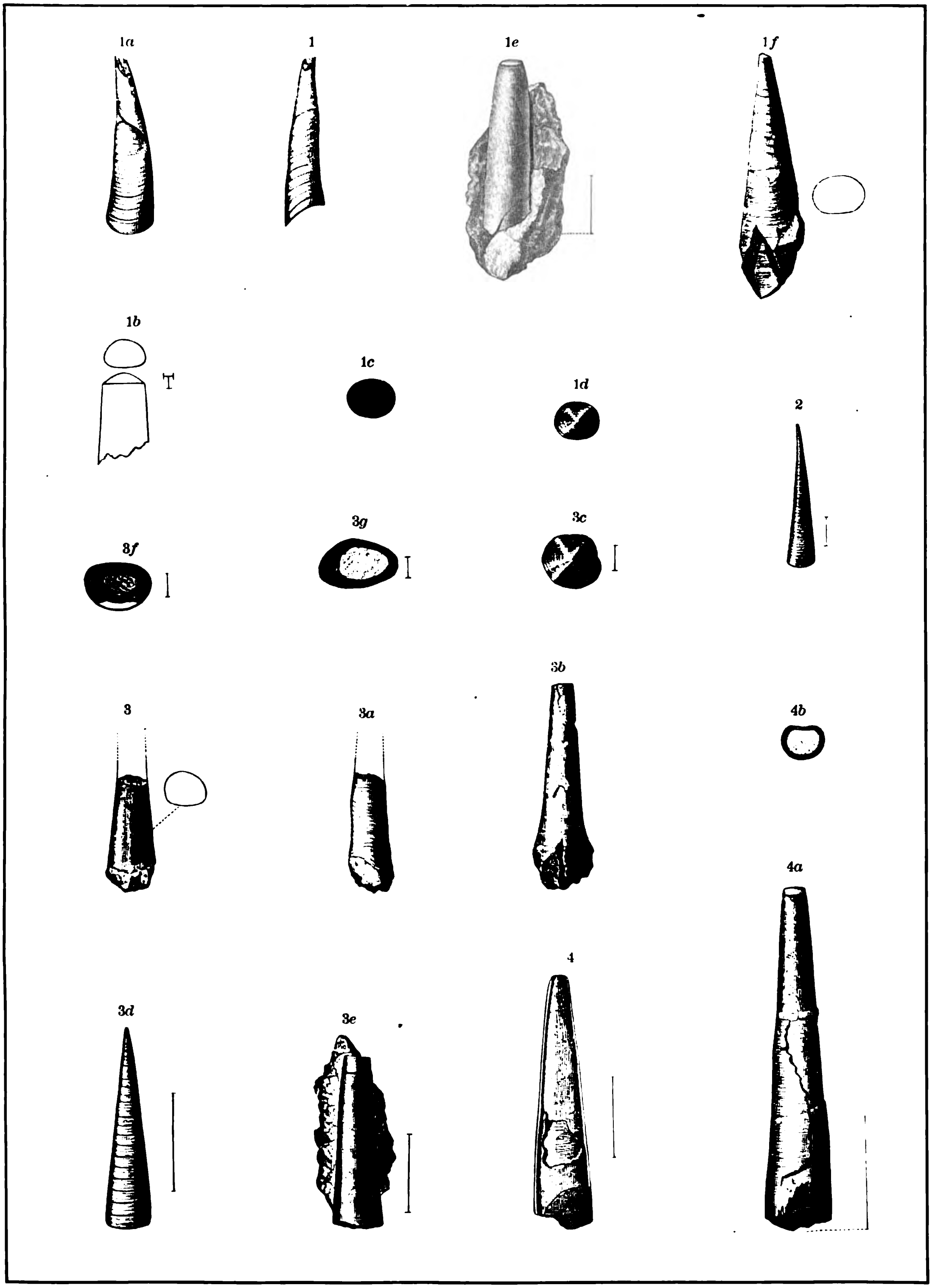
1*l*. Broken sections of this species in association with sections of several other species.



PTEROPODA.

PLATE LXXVII.

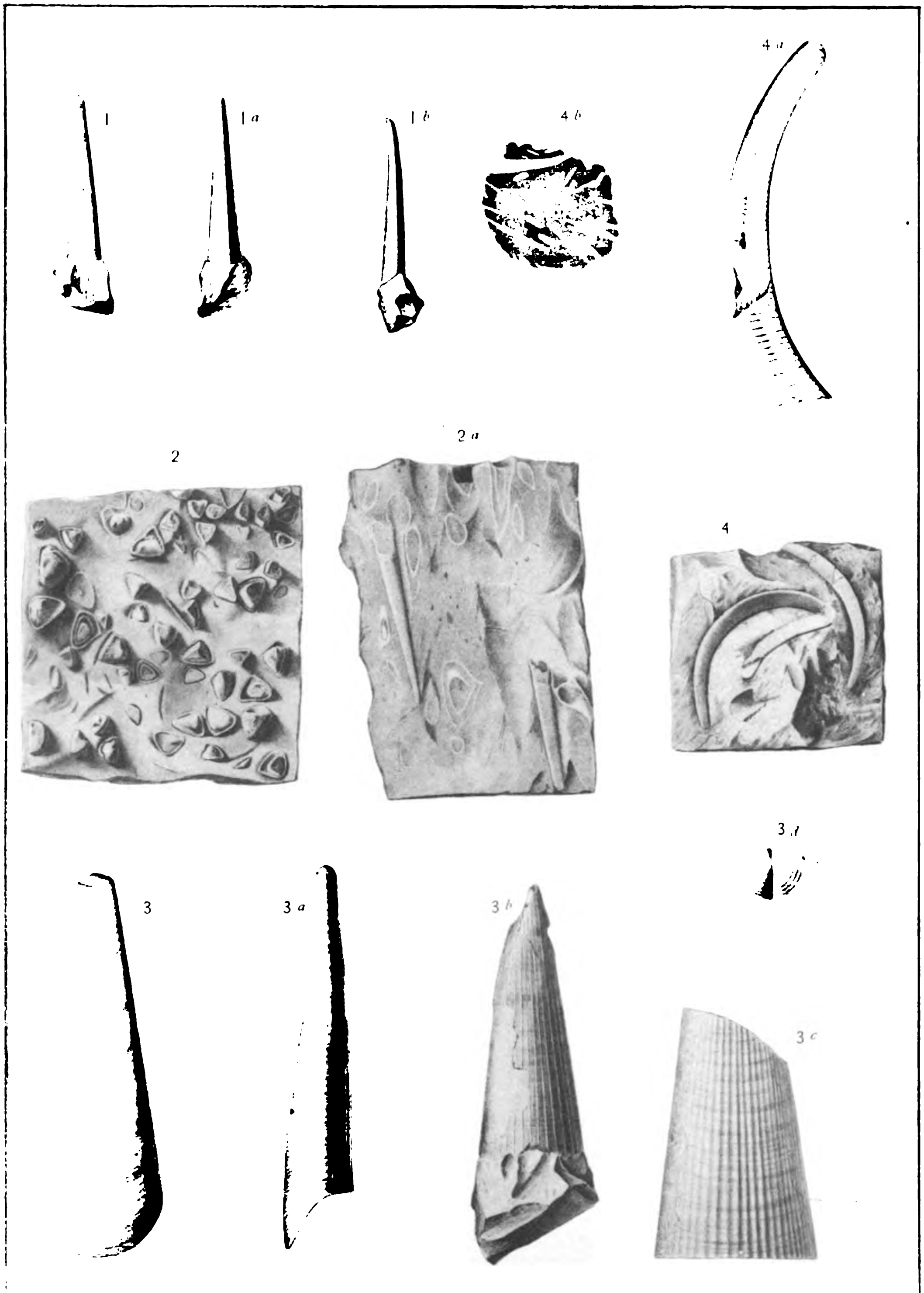
PLATE LXXVII.



PTEROPODA.

PLATE LXXVIII.

Plate LXXVIII.



Forbes Co., Boston.

PTEROPODA.

PLATE LXXIX.

Plate LXXIX.

Page.

HYOLITHELLUS MICANS 624

FIG. 1. A fragment of the shell remaining in a natural mold, enlarged to show the annulations. Collection U. S. National Museum.

1*a*. Enlargement of the terminal portion of a tube. Collection U. S. National Museum.

1*b*. A crushed specimen in shale. Collection U. S. National Museum.

1*c*. Exterior of operculum. Collection U. S. National Museum.

1*d*. Cast of the interior of an operculum. Collection U. S. National Museum.

1*e*. Interior of an operculum. Collection U. S. National Museum. All specimens from Troy, N. Y., except 1*b*, which was found one mile below Schodack Landing.

HYOLITHELLUS MICANS *var.* RUGOSA 624

FIG. 2. Enlargement of fragment, to show the rugose surface. Collection U. S. National Museum.

SALTERELLA CURVATUS 625

FIG. 3, 3*a*. Illustrations of the type specimens. (After Shaler & Foerste.)

SALTERELLA RUGOSA 625

FIG. 4. Enlarged view of a specimen from L'Anse au Loup. Collection U. S. National Museum.

SALTERELLA PULCHELLA 625

FIG. 5. Lateral view of a specimen from a pebble in the Point Levis limestone conglomerate. Collection U. S. National Museum.

5*a*. A specimen from same locality, showing the aperture and one of the inner tubes. Collection U. S. National Museum.

5*b*, 5*c*. Casts of specimens in the "Red Sandrock," east of Highgate Springs, Vt. Collection U. S. National Museum.

5*d*, 5*e*. Specimens from the "Winooski" marble, near Swanton, Vt. These probably belong to a different species. Collection U. S. National Museum.

COLEOLOIDES TYPICALIS 624

FIG. 6. Enlargement to three diameters, to show form of tube. Collection U. S. National Museum.

6*a*. Further enlargement to show the elevated spiral striæ.

VOLBORTHELLA TENUIS 722

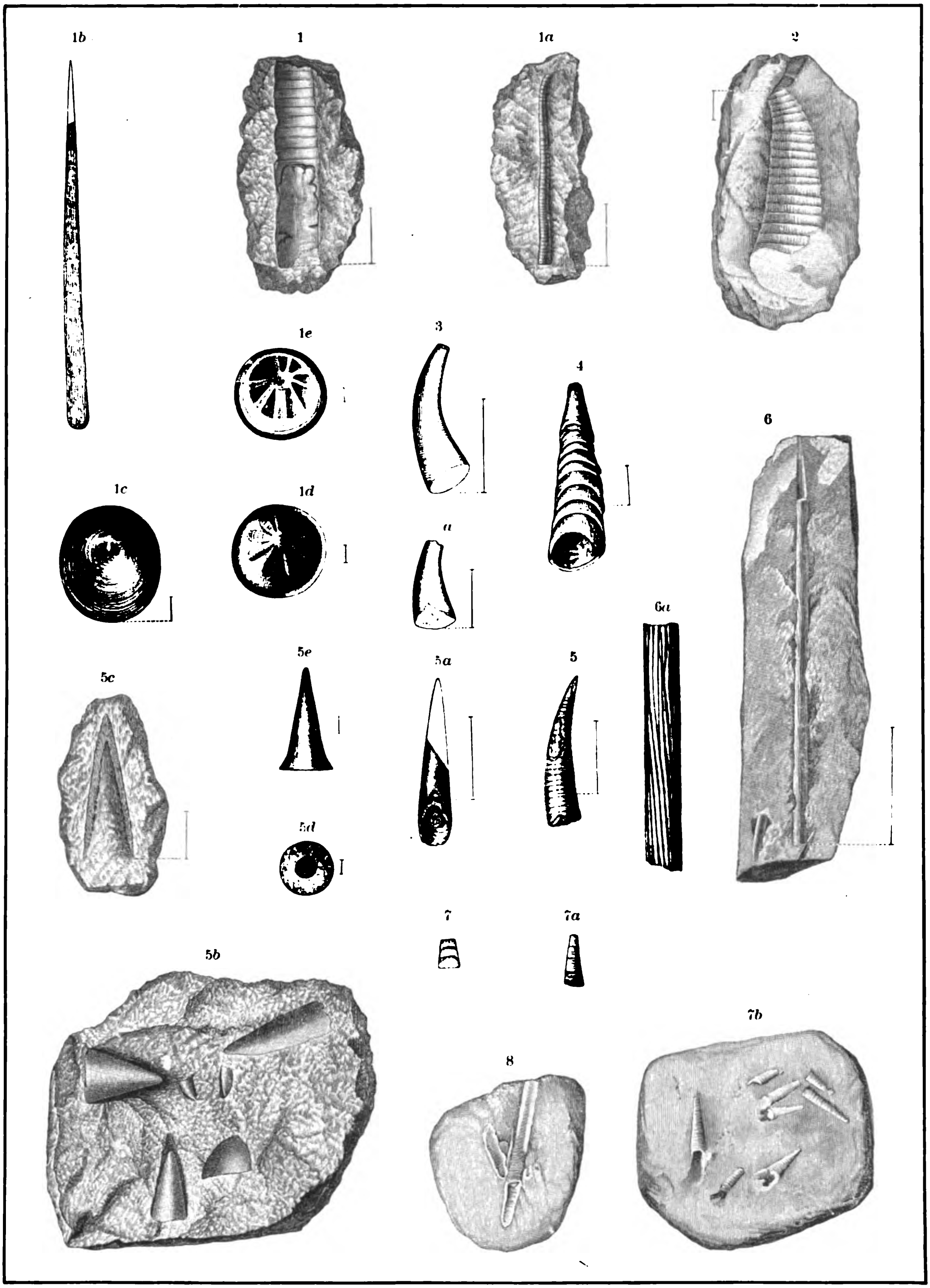
FIG. 7. Longitudinal section of tube. (After Schmidt.)

7*a*. Exterior view of tube. (After Schmidt.)

7*b*. Fragment of rock with several tubes upon it. (After Schmidt.)

PLATYSOLENITES ANTIQUISSIMUS 722

FIG. 8. Large examples on a fragment of sandstone. (After Schmidt.)



PTEROPODA.

PLATE LXXX.

Plate LXXX.

Leperditia (I.) dermatoides 626

Fig. 1. Left (?) valve and outlines of its convexity.

1*a*. Enlargement to show punctate surface and the wrinkled appearance of the test, as seen on some specimens.

Aristozoe troyensis 628

Fig. 2. Right valve, from Troy, N. Y. Collection U. S. National Museum.

2*a*. Cast of left valve, from Washington County, N. Y. Collection U. S. National Museum.

Aristozoe rotundata 627

Fig. 3. Cast of the right valve. A row of vascular markings are quite distinctly shown on the lower portion of the valve.

Nothozoe vermontana 628

Fig. 4. A nearly circular valve. Collection U. S. National Museum.

4*a*, 4*b*. Right and left valves, embedded in the "granular quartz" rock. Collection U. S. National Museum.

Agnostus desideratus 629

Fig. 5. Head shield, enlarged. Collection U. S. National Museum.

Agnostus, sp. undetermined 630

Fig. 6. Head shield.

6*a*. Pygidium associated with the head represented by Fig. 6.

Microdiscus parkeri 632

Fig. 7, 7*a*. Head and pygidium, enlarged. Collection U. S. National Museum.

Agnostus ? nobilis 629

Fig. 8. Copy of Mr. S. W. Ford's original figure. Type specimen lost.

Microdiscus connexus 631

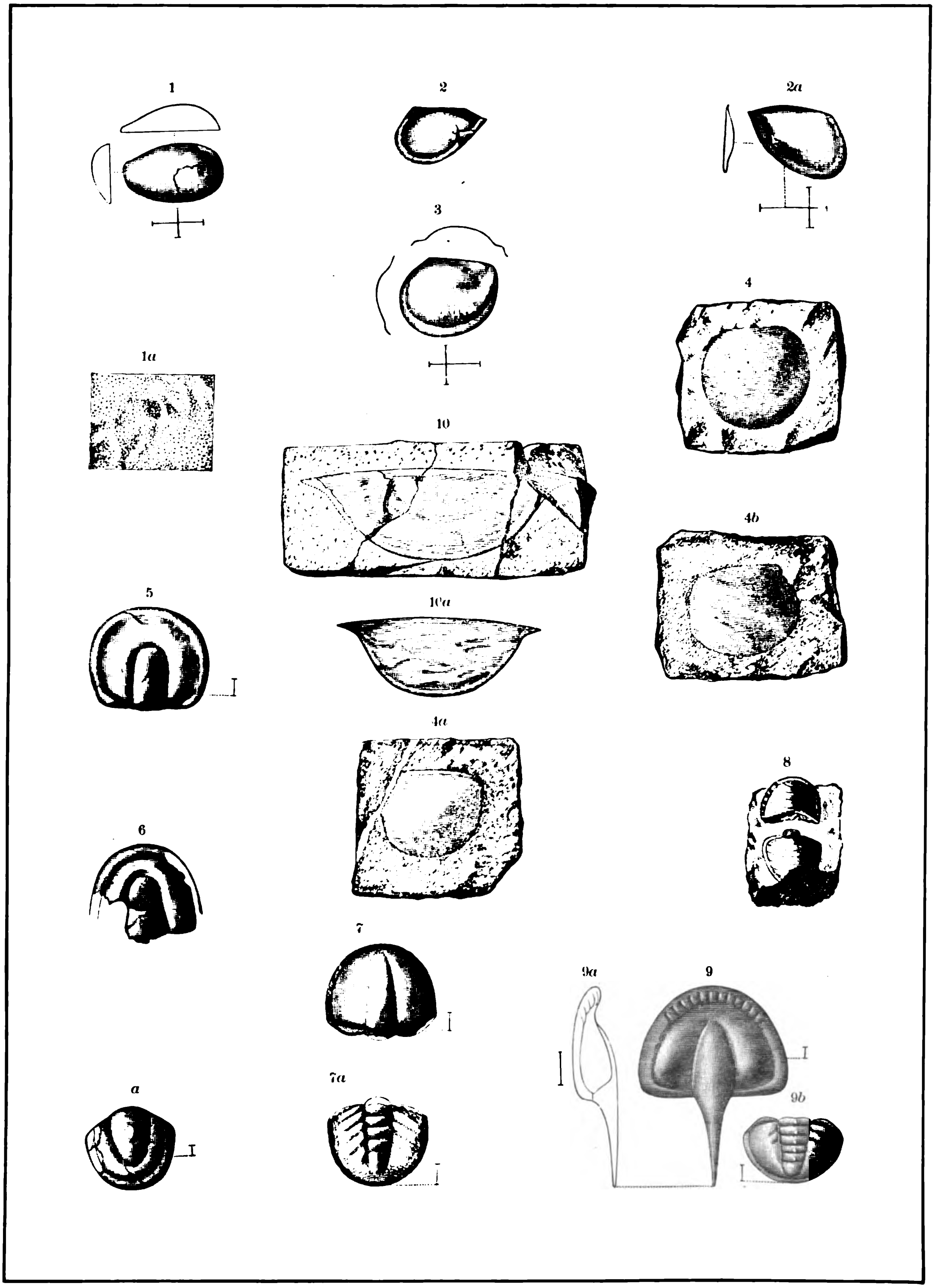
Fig. 9, 9*a*. Summit and side views of head.

9*b*. Associated pygidium.

Isoxys chilhoweana 626

Fig. 10. Cast in clay shale of a portion of one valve and on the left side a portion of the opposite valve. Natural size. Collection U. S. National Museum.

10*a*. A very perfect specimen showing the characters of the carapace as far as known. Collection U. S. National Museum.



CRUSTACEA AND TRILOBITA.

PLATE LXXXI.

Plate LXXXI.

Page.

MICRODISCUS HELENA 632

FIG. 1. View of head from above, with outline of side view. Collection U.S. National Museum.

1*a*. Pygidium associated with this species.

MICRODISCUS BELLIMARGINATUS 630

FIG. 2. Copy of original figure of the species, by Schaler & Foerste.

2*a*. View of head from above, with outline of side view. Collection U.S. National Museum.

2*b*. Pygidium associated with the head represented by Fig. 2*a*. Collection U.S. National Museum.

MICRODISCUS MEEKI 632

FIG. 3. View of head from above, and side view in outline, drawn from type specimen. Collection S. W. Ford.

MICRODISCUS LOBATUS 632

FIG. 4. Head, very much enlarged. Collection U.S. National Museum.

4*a*. Head, showing considerable variation from 1. Collection U.S. National Museum.

4*b*. Pygidium, very much enlarged. Collection U.S. National Museum. Original specimens from Troy, N. Y.

MICRODISCUS SPECIOSUS 632

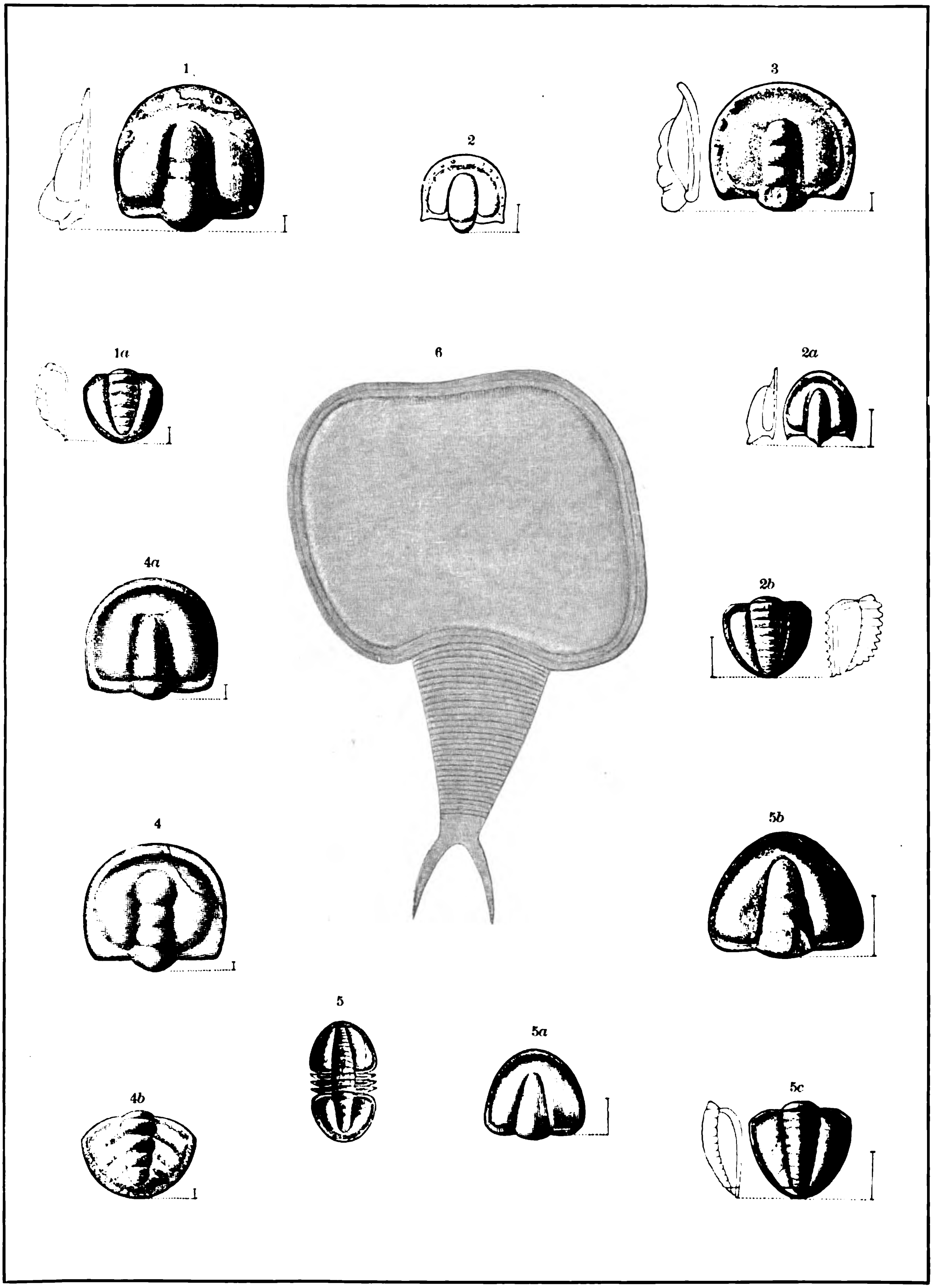
FIG. 5. Entire specimen from Washington County, N.Y. Collection U.S. National Museum.

5*a*, 5*b*. Two very perfect head shields. Collection U. S. National Museum.

5*c*. Pygidium associated with 5*a*.

PROTOCARIS MARSHI 629

FIG. 6. Figure given in Bulletin 10, U. S. Geological Survey. Pl. X. Description on page 50. Reproduced here in order to show the Lower Cambrian fauna, as known to me, in one series of plates. Collection U.S. National Museum.



CRUSTACEA AND TRILOBITA.

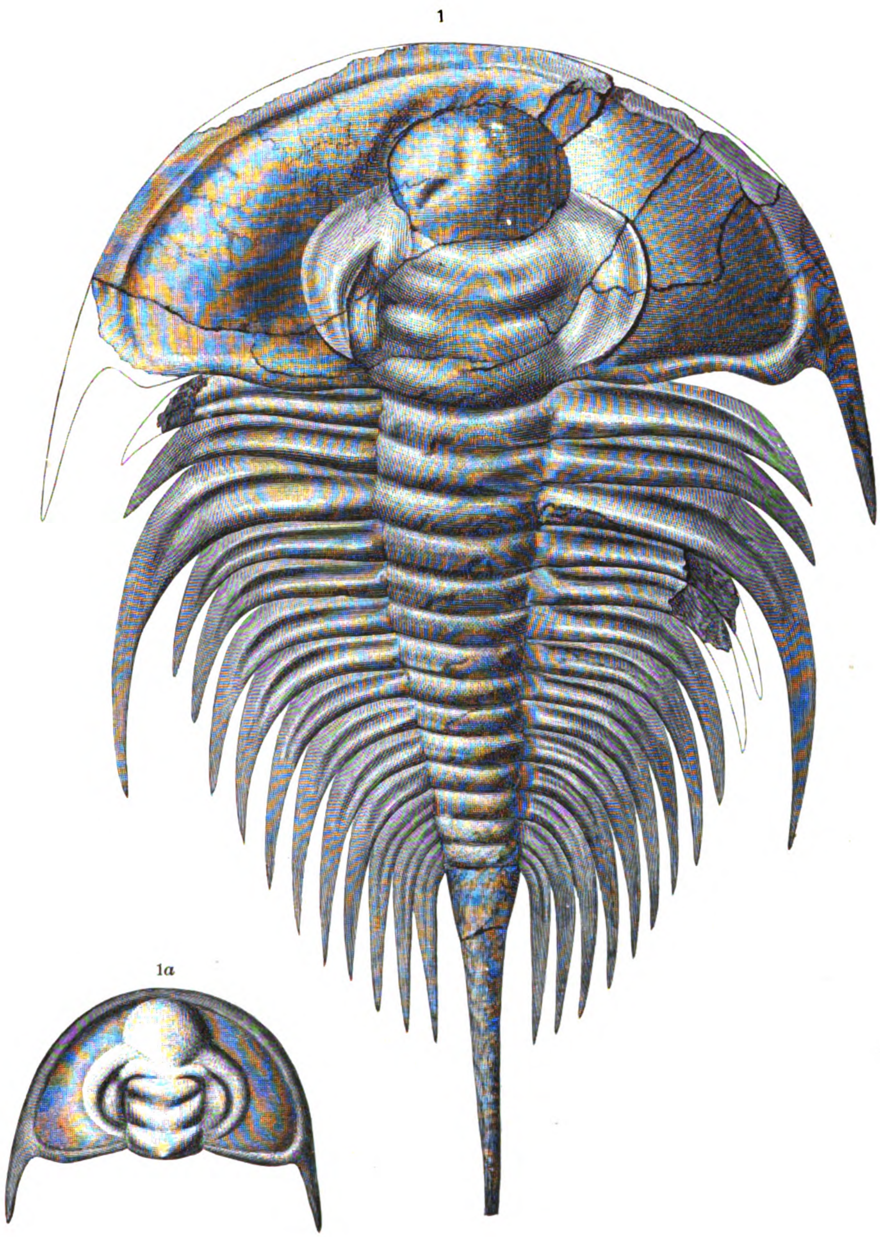
PLATE LXXXII.

PLATE LXXXII.

FIG. 1. A large individual with the third segment unusually prolonged. From the type locality at Parker's quarry, Georgia, Vt. Collection U.S. National Museum.

1*a*. A very perfect head, preserving the natural convexity, from the decomposed magnesian limestone east of Swanton. As portions of the specimen were broken away other specimens were used to aid the draughtsman in representing an entire head. Collection U.S. National Museum.

(See Pl. LXXXIII.)



TRILOBITA.

PLATE LXXXIII.

Plate LXXXIII.

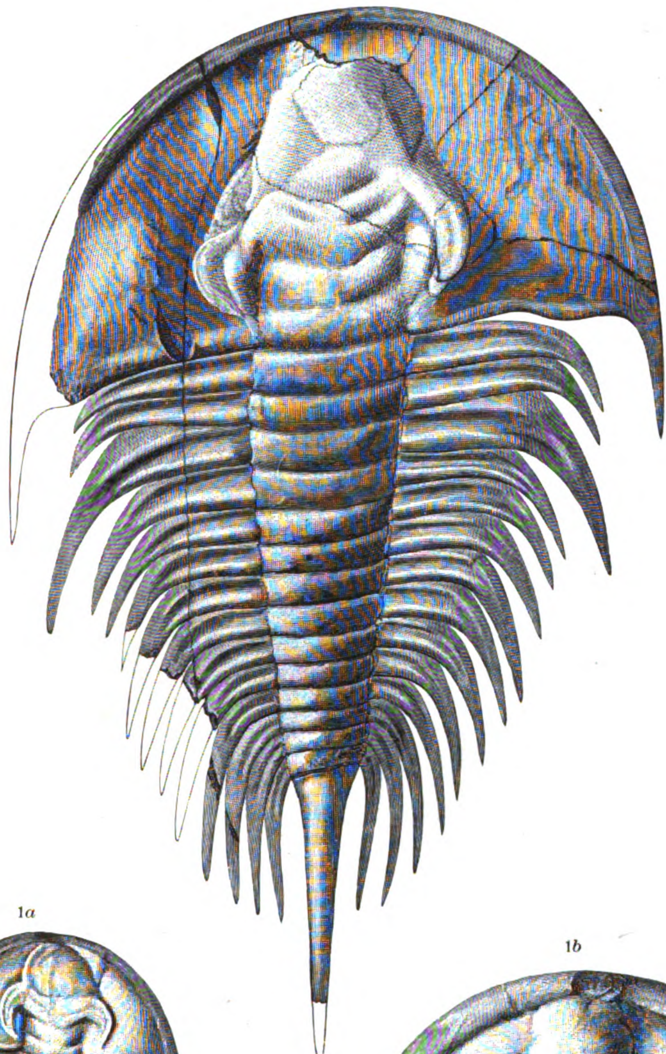
Fig. 1. A nearly perfect specimen from Parker's quarry. As compared with Fig. 1, Pl. LXXXII, this may be considered the narrow form of the species. Collection U. S. National Museum.

1*a*. Entire specimen from fine argillaceous shales at Parker's quarry. Collection U. S. National Museum.

1*b*. Head, with an unusually broad border, from Swanton, Vt. Collection U. S. National Museum.

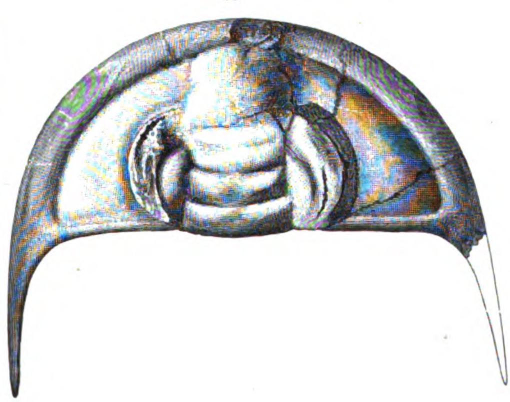
(See Pl. LXXXII.)

1



1a

1b



TRILOBITA.

PLATE LXXXIV.

Plate LXXXIV.

Page.

Olenellus gilberti 636

Fig. 1. Normal form of the species, except the unusual prolongation of the third segment. Collection U. S. National Museum.

1*a*. Outline of the specimen from which Fig. 1 was enlarged. Natural size.

1*b*, 1*c*. Top and lateral views of type specimen from Pioche, Nev. Collection U. S. National Museum.

1*d*. Side of head, showing line of narrow groove on inside of the test at *o*, *x*, corresponding to position of suture in Paradoxides. Collection U. S. National Museum.

1*e*. A portion of a head referred to this species, showing the same carrying forward of the genal angles that is shown in specimens from the Eureka district and Groom district, Nevada. Collection U. S. National Museum.

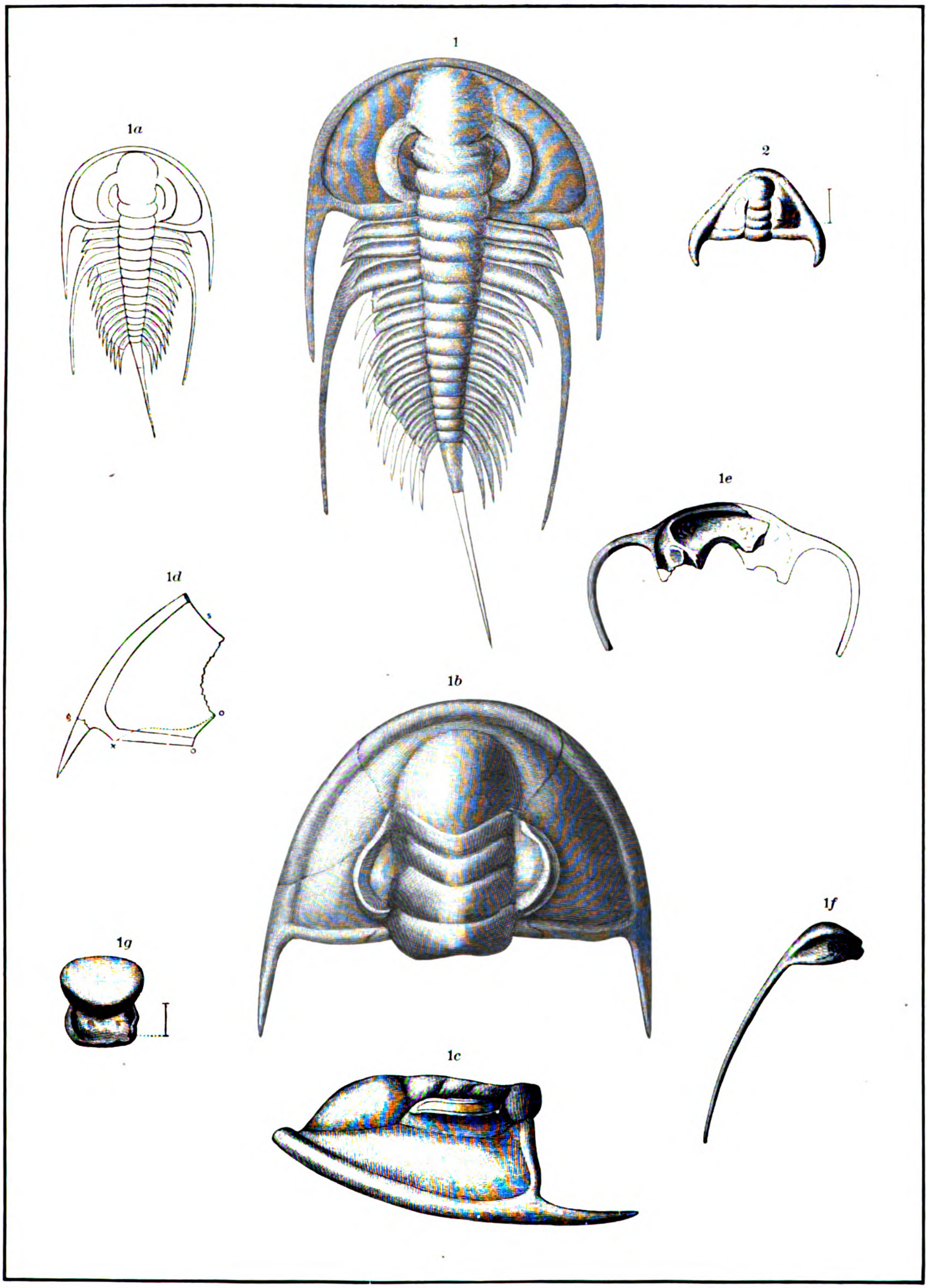
1*f*. Prolonged pleura of third (?) segment of this species. Associated with 1*g*.

1*g*. Hypostoma associated with this species in the Eureka district, Nevada. Collection U. S. National Museum.

(See Pls. LXXXV and LXXXVI.)

Olenellus iddingsi 636

Fig. 2. View of the type specimen, enlarged to two diameters. Collection U. S. National Museum.



TRILOBITA.

PLATE LXXXV.

PLATE LXXXV.

Page.

FIG. 1. Specimen broadened by longitudinal compression. The head shows features observed in the series of heads figured on Pl. LXXXVI. The long, slender extremities of the genal spines and the terminations of the third thoracic segments are not often observed. Collection U. S. National Museum.

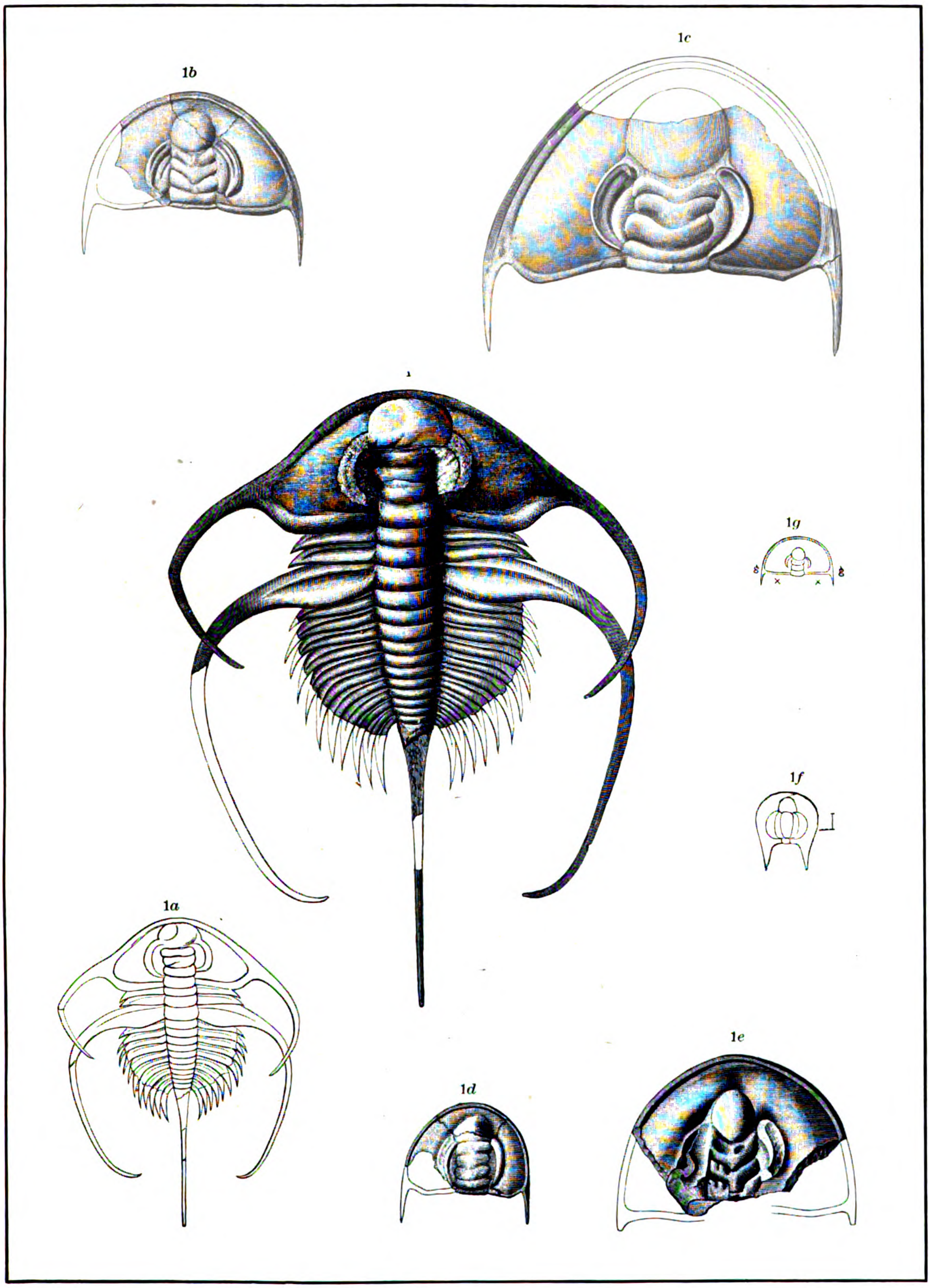
1*a*. Outline of figure from which Fig. 1 was enlarged. Natural size.

1*b*, 1*c*, 1*d*. Figures of the type specimens illustrated by Dr. White, from Pioche, Nev.

1*e*, 1*f*. Specimens from the Eureka district, Nev. Collection U. S. National Museum.

1*g*. A worn specimen of a young individual of this species or *Olenellus iddingsi*. Groom district, Nev. Collection U. S. National Museum.

(See Pls. LXXXIV and LXXXVI.)



TRILOBITA.

PLATE LXXXVI.

PLATE LXXXVI.

Page.

OLENELLUS GILBERTI 636

FIG. 1, 1c. Smallest specimen of the head in the collection; eyes distinct from the glabella.

1a. A larger specimen than 1, but with the genal angles carried forward, while the eyes are close to the glabella.

1b. Genal angles normal, but eyes united to the glabella by an ocular ridge.

1d. Head showing the anterior position of the genal spines, *gg*, and the angles of the posterior margin, *xx*, extravagantly developed. The difference in the length of the ocular ridges of the right and left side is also very marked. Natural size.

1e. The smallest individual in which the depression indicating posterior course of the false facial suture was observed. The outline of the head is much like that of Fig. 1. Natural size.

1f. A specimen from southern Nevada, with the genal spines still further advanced than those of 1d.

1g. Form intermediate in contour of head between Figs. 1d and 1e. *gg*, Genal angles and spines; *xx*, angles of the posterior margin. Natural size.

1h. The eyes in this specimen are no longer pedunculated or united to the glabella by an ocular ridge, and the genal angles are more posterior. The course of the false facial suture, in front of the eye, is also seen for the first time. Naturalsize.

1i. Example in which the genal angles are in the same position as in the adult individual in species of this genus. The eyes are more embryonic in character than in the preceding example. Natural size.

1k. Broader and more common form, showing the same peculiarities as Fig. 1m. Natural size.

1l. The right and left sides are irregularly developed, the genal spine on the left side being more anterior in position. The course of the false facial suture is traced in accordance with its position, as observed in Fig. 1h. Natural size.

1m. Narrow form, with the eyes of the adult type, and having the genal angles carried forward, as in the younger indiviuals, 1c, 1e, 1h. Natural size.

All the originals of the above are in the collection of the U. S. National Museum.

(See Pls. LXXXIV and LXXXV.)

OLENELLUS (H.) KJERULFI 634

FIG. 2. Outline of head showing the position of the genal angles and angles of the posterior margin, *xx*, with the interocular spine; also the ocular ridge (*a*) uniting the glabella and eyes. (After Linnarsson.)

OLENELLUS (M.) ASAPHOIDES 637

FIG. 3. Embryonic form, showing the circular outline, the genal spines in close proximity to the interocular spines. X 35. (After Ford.) Collection S. W. Ford.

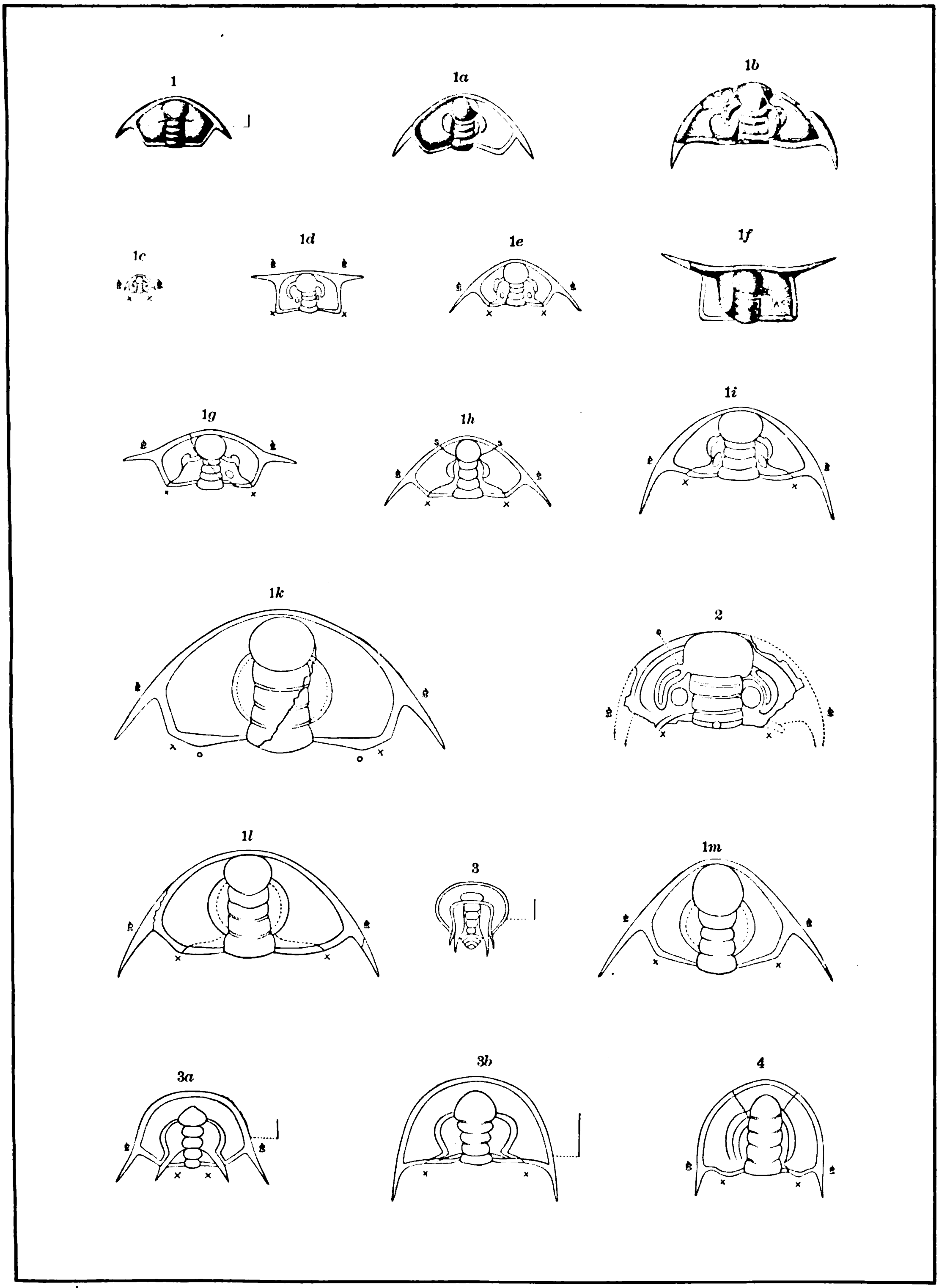
3a. Another phase of the development of this species, succeeding, with probably intermediate forms, Fig. 3. The position of the genal spine, *gg*, and the false sutures cutting the posterior margin at the angles *xx*, is comparable to the same in Fig. 1e. X 5. (After Ford.) Collection S. W. Ford.

3b. Normal adult type of the head of this species. X 2. (After Ford.) Collection S. W. Ford.

(See Pls. LXXXVIII, LXXXIX and XC.)

OLENELLUS GILBERTI 636

FIG. 4. Narrow form of head, that shows the angles in the posterior margin, *xx*, slightly developed. Natural size. (After White.) Collection U. S. National Museum.



TRILOBITA.

PLATE LXXXVII.

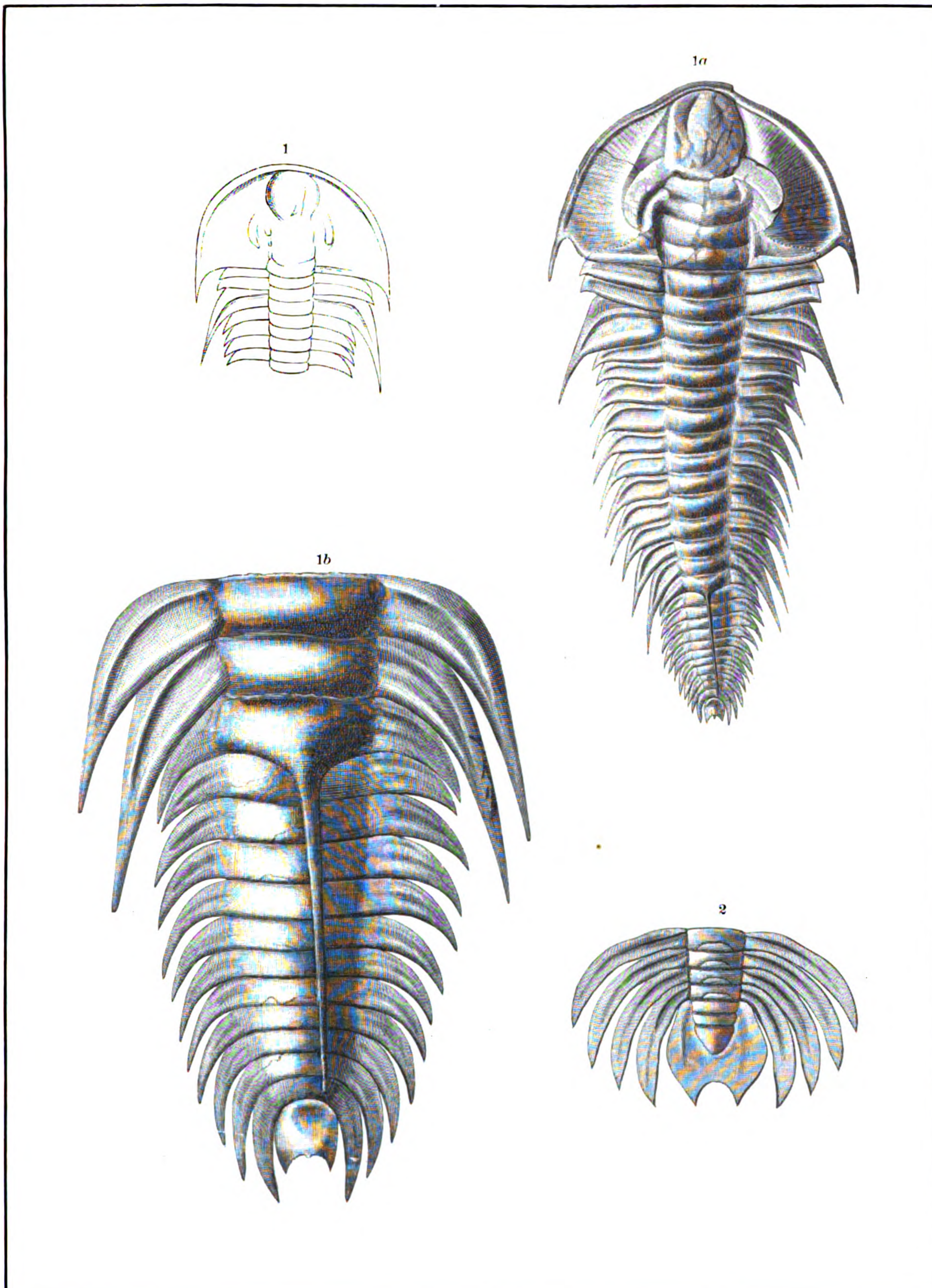
Plate LXXXVII.

Fig. 1. Copy of the original figure of the type specimen of the species. Collection American Museum of Natural History, New York City.

1*a*. A very perfect specimen from the collection of Mr. E. Hurlburt. The matrix is in the U. S. National Museum.

1*b*. Enlargement of the posterior portion of 1*a*. The spine projecting from the fifteenth segment is flattened down on the thorax more than is shown in the figure.

Fig. 2. Pygidium and four posterior thoracic segments, enlarged after Barrande (Syst. Sil. Bohême, vol. i, Pl. ix, Fig. 31, 1852). It is introduced for comparison with Fig. 1*b*.



TRILOBITA.

PLATE LXXXVIII.

Plate LXXXVIII.

FIG. 1. The youngest stage of development of this species yet observed by the writer. Length, four-fifths of one millimeter. Collection U. S. National Museum.

1*a*. A slightly larger specimen than that represented by 1*b*. It is 1.75^{mm} in length. Collection U. S. National Museum.

1*b*. A young individual, showing embryonic features in the head and the great prolongation of the third thoracic segment. Collection S. W. Ford.

1*c*. A larger specimen than that represented by Fig. 1*b*, in which the third thoracic segment is shorter. Collection S. W. Ford.

1*d*. A small individual in which the third segment of the thorax is the same as the other segments, and the head has the essential characters of the adult with the exception of the slight prolongation of the interocular spine. Collection S. W. Ford.

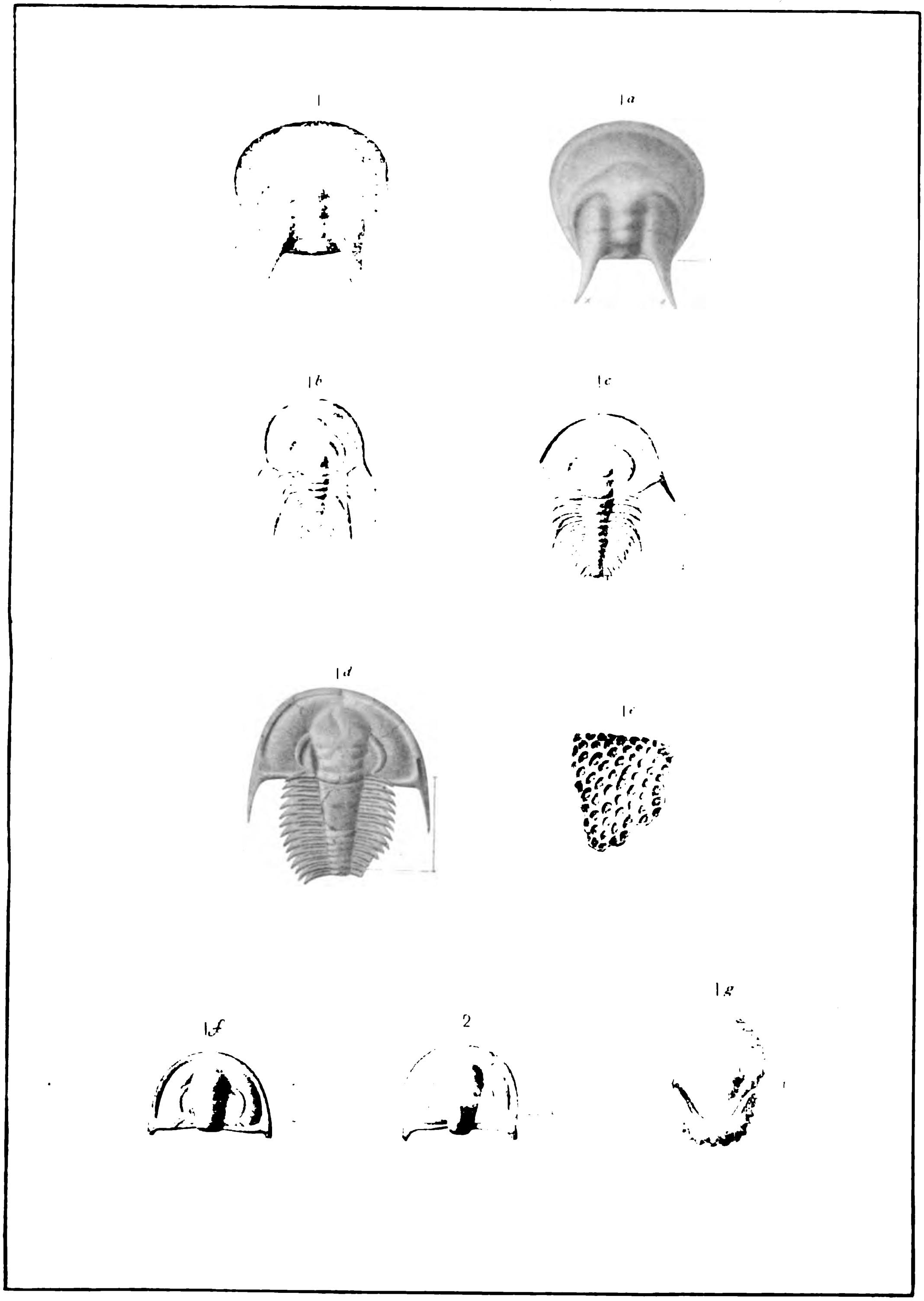
1*e*. Enlargement of a portion of the surface of the lateral cheek.

1*f*. Enlargement of a small head, for comparison with Fig. 2.

1*g*. Hypostoma referred to this species. Collection U. S. National Museum.

(See Pls. LXXXVI, LXXXIX and XC.)

FIG. 2. Enlargement of the type specimen. The glabella is slightly crushed, so as to make it narrower at the base than when in a natural condition. Compare with Fig. 1*f*. Collection U. S. National Museum.



Forbes Co., Boston.

TRILOBITA.

PLATE LXXXIX.

Plate LXXXIX.

Page.

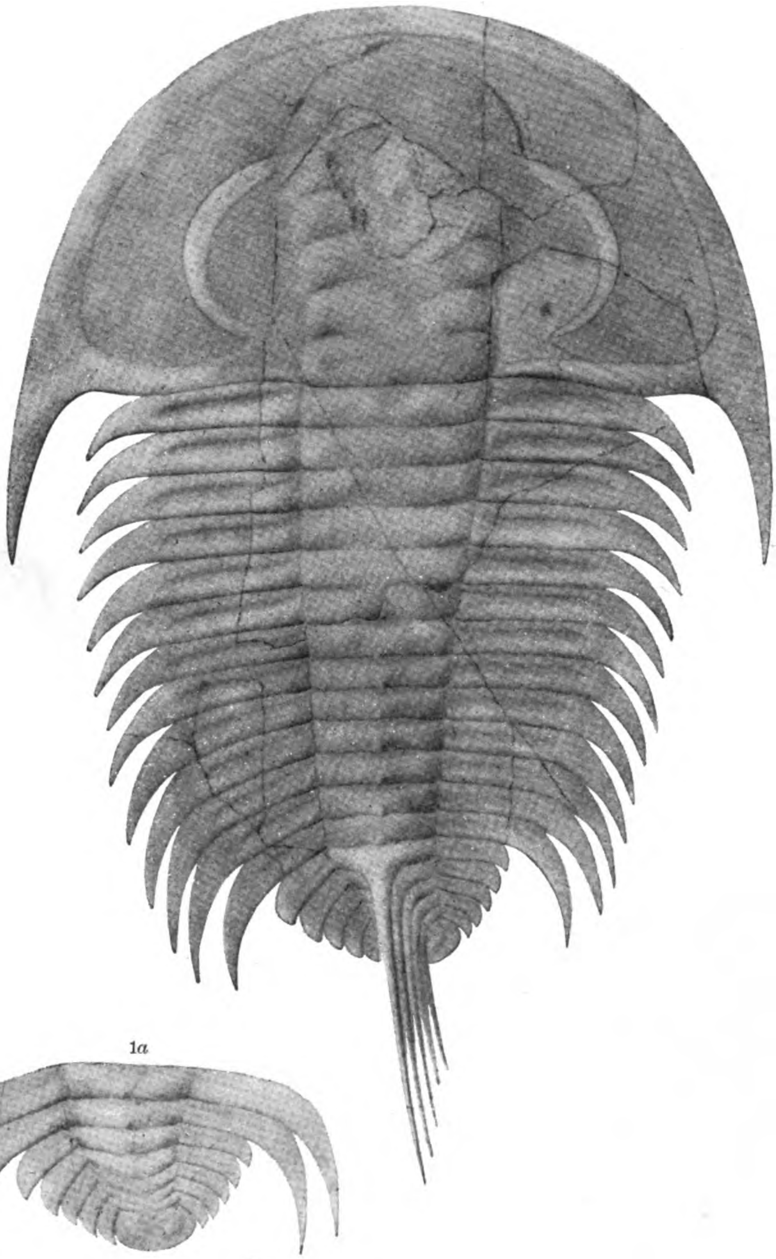
Olenellus (Mesonacis) asaphoides 637

Fig. 1. A specimen from the type locality of the species in Washington County, N. Y. The spines on the posterior segments have been restored from another specimen. Collection U. S. National Museum.

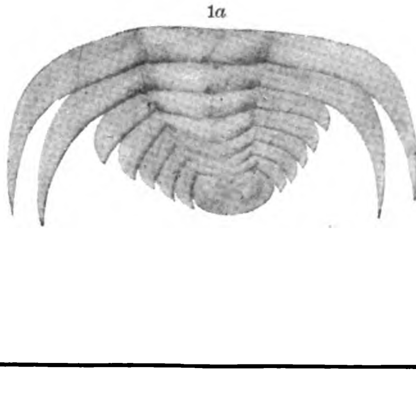
1*a*. Pygidium and posterior segments of Fig. 1, without the thoracic spines.

(See Pls. LXXXVI, LXXXVIII and XC.)

1



1a



TRILOBITA.

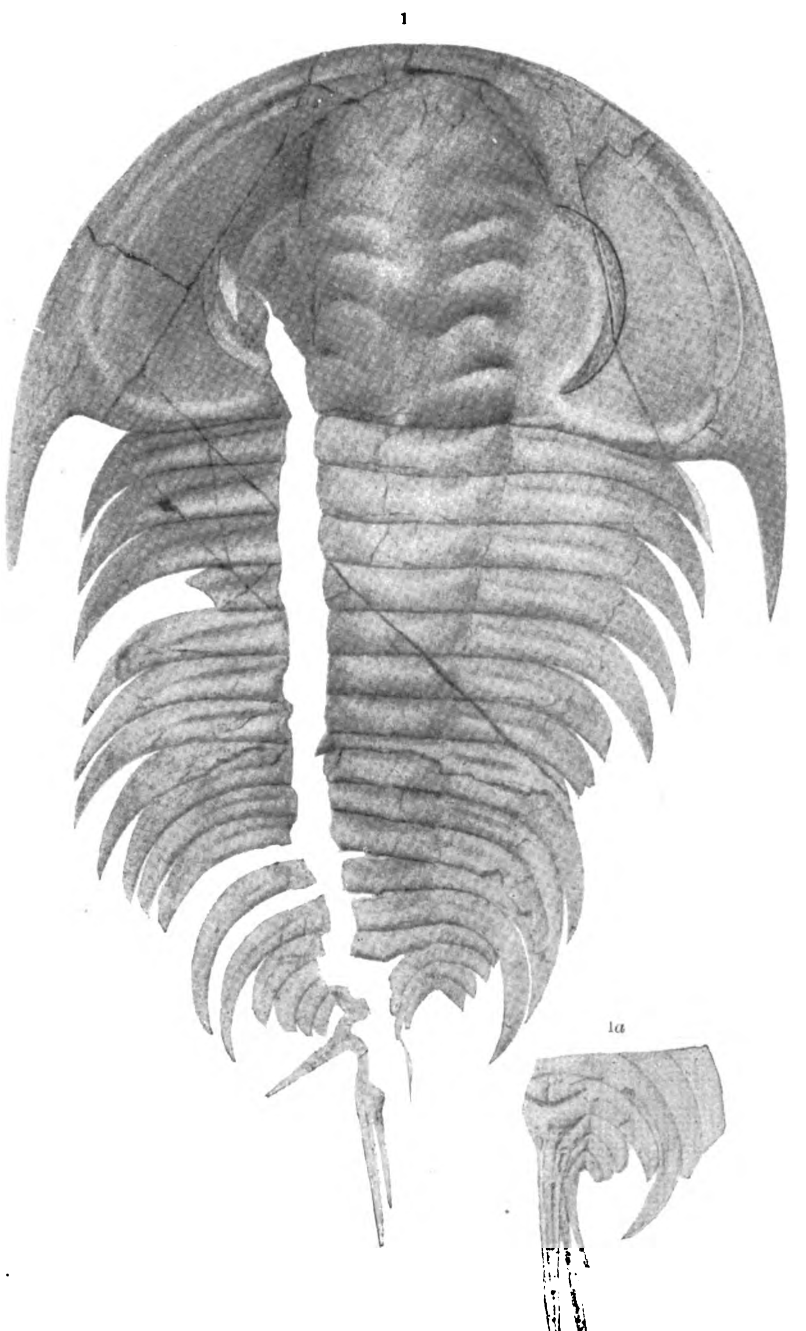
PLATE XC.

PLATE XC.

FIG. 1. A large individual from the type locality of the species. No attempt at restoration is made in any part. Collection U. S. National Museum.

1a. Fragment preserving the posterior segments and spines. Collection U. S. National Museum.

(See Pls. LXXXVI, LXXXVIII and LXXXIX.)



TRILOBITA.

PLATE XCI.

PLATE XCI.

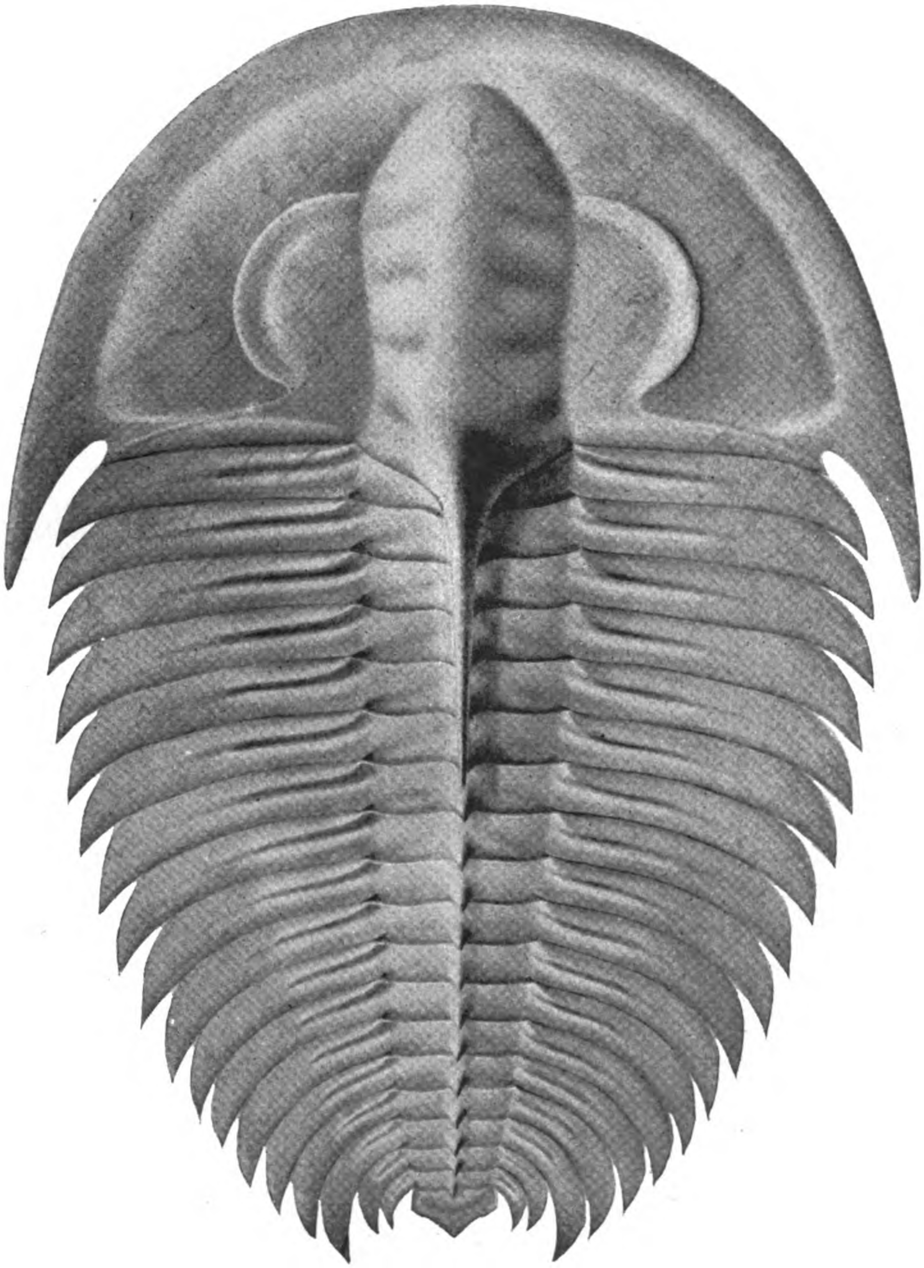
Page

OLENELLUS (HOLMIA) BRÖGGERI 638

FIG. 1. Restoration of this species, based on a large number of partially preserved fragments in the limestone and numerous nearly entire specimens compressed in the shale. The specimens in the limestone show the convexity and those in the shale the general proportions and number of segments.

(See Pl. XCII.)

1



TRILOBITA.

PLATE XCII.

PLATE XCII.

Page.

OLENELLUS (HOLMIA) BRÖGGERI 638

FIG. 1. An uncompressed head in the decomposed limestone. Collection U. S. National Museum.

1*a*. Outline view of the side of 1.

1*b*. Lateral cheek, showing genal spine. Collection U. S. National Museum.

1*c*. Pygidium and posterior segments. Collection U. S. National Museum.

1*d*. Termination of pleura, enlarged to two diameters. Collection U. S. National Museum.

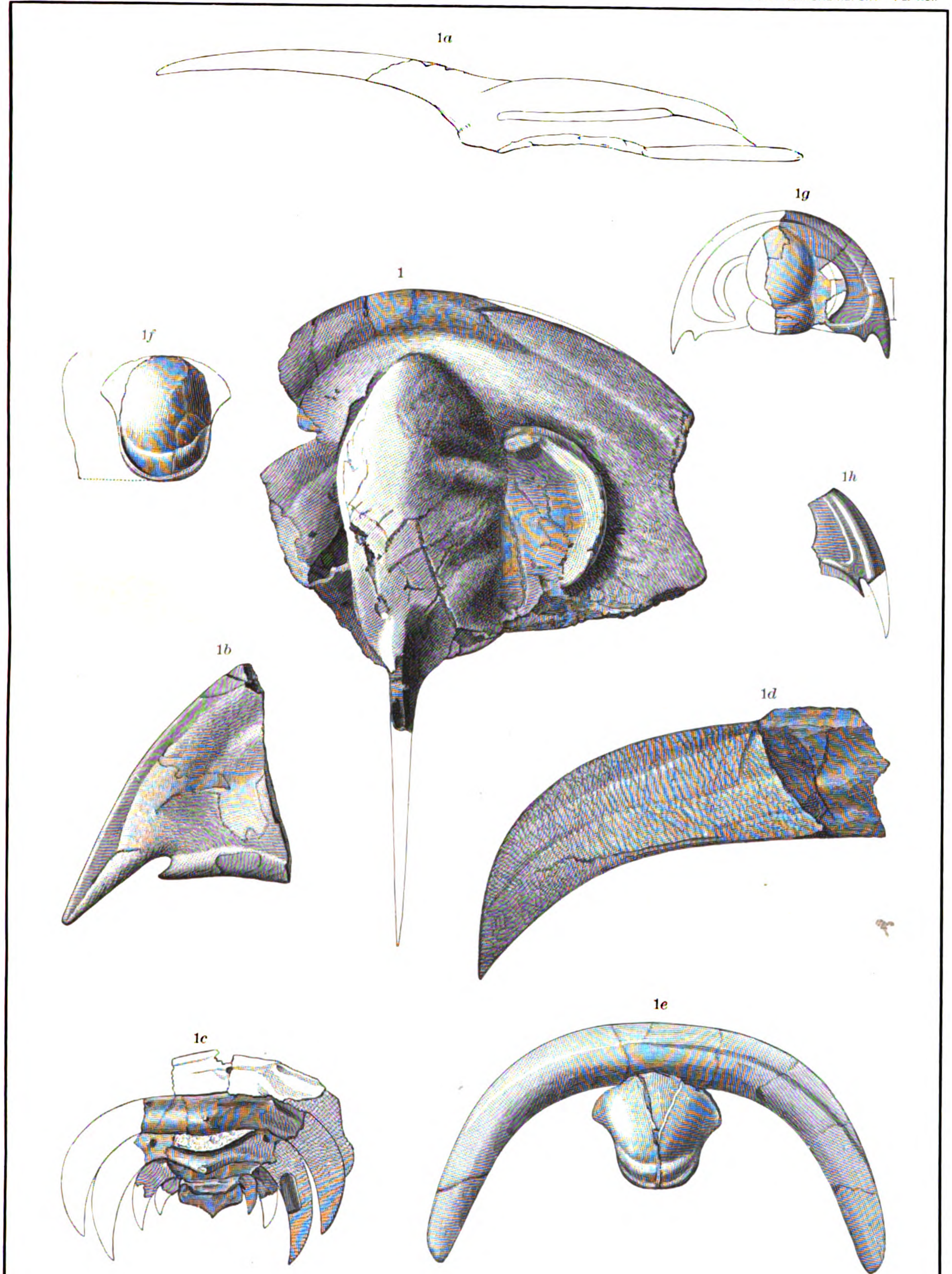
1*e*. Hypostoma attached to the doublure. Collection U. S. National Museum.

1*f*. Hypostoma. Collection U. S. National Museum.

1*g*. A small head. Collection U. S. National Museum.

1*h*. Small lateral cheek, in which the genal spine is unusually short. Collection U. S. National Museum.

(See Pl. XCI.)



TRILOBITA.

PLATE XCIII.

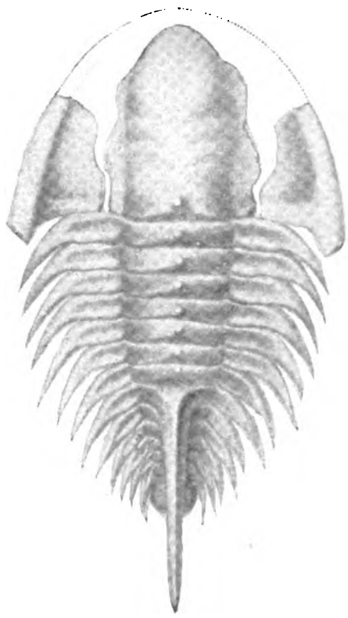
Plate XCIII.

	Page.
Olenellus (Mesonacis) mickwitzia	634
Fig. 1. This figure is taken from Schmidt's work,[1] and represents about all that was known of the species at the date of its publication.	
Olenellus (Holmia) kjerulfi	634
Fig. 2. A beautiful illustration of this species. (After Holm.)[2]	

[1] Über eine neuentdeckte untercambrische fauna in Estland; F. Schmidt. Mém. Acad. Imp. Sci. St. Pétersbourg, V. II, vol. 36. No. 2, 1888, pp. 1-27, Pls. i, ii.

[2] Om Olenellus kjerulfi; G. Holm. Geol. Fören. Förhandl., Bd. 9, 1887.

1



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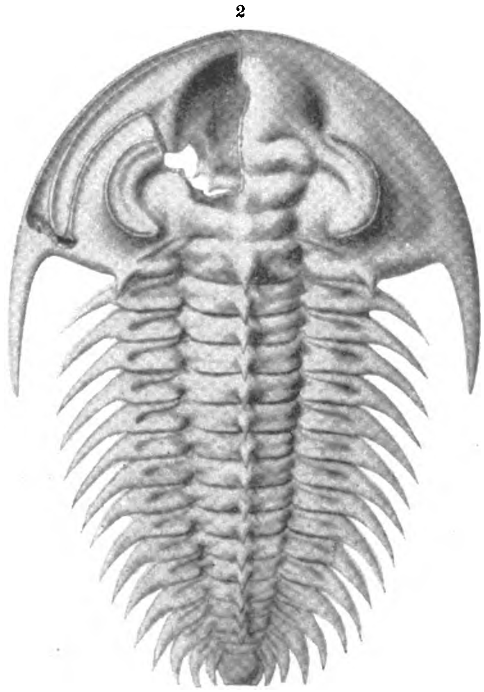


TRILOBITA.

PLATE XCIV.

Plate XCIV.

Page.

Olenoides curticei 752

Fig. 1. This species is from the Middle Cambrian of the Coosa Valley, Georgia. It is introduced to illustrate the characters of the genus Olenoides. Collection U.S. National Museum.

1*a*. View of section of a specimen buried in a flint nodule. Collection U.S. National Museum.

Olenoides marcoui 642

Fig. 2, 2*a*. Head and pygidium from the arenaceous shales of Parker's quarry. Collection U.S. National Museum.

2*b*. Interior of pygidium. Collection U.S. National Museum.

Olenoides fordi 641

Fig. 3. Head with exception of free cheeks. Washington County, N.Y. Collection U.S. National Museum.

3*a*, 3*b*. Pygidium and free cheek associated with 3. Collection U.S. National Museum.

3*c*. Side outline of 3*a*.

Olenoides quadriceps 646

Fig. 4. Original figure of *Dikellocephalus quadriceps* Hall & Whitfield, enlarged to three diameters. Collection U. S. National Museum.

4*a*, 4*b*. Top and side views of associated pygidium. Collection U.S. National Museum.

4*c*. Side view of Fig. 4.

4*d*. Specimen from the Olenellus zone of the Eureka district, Nevada. Collection U.S. National Museum.

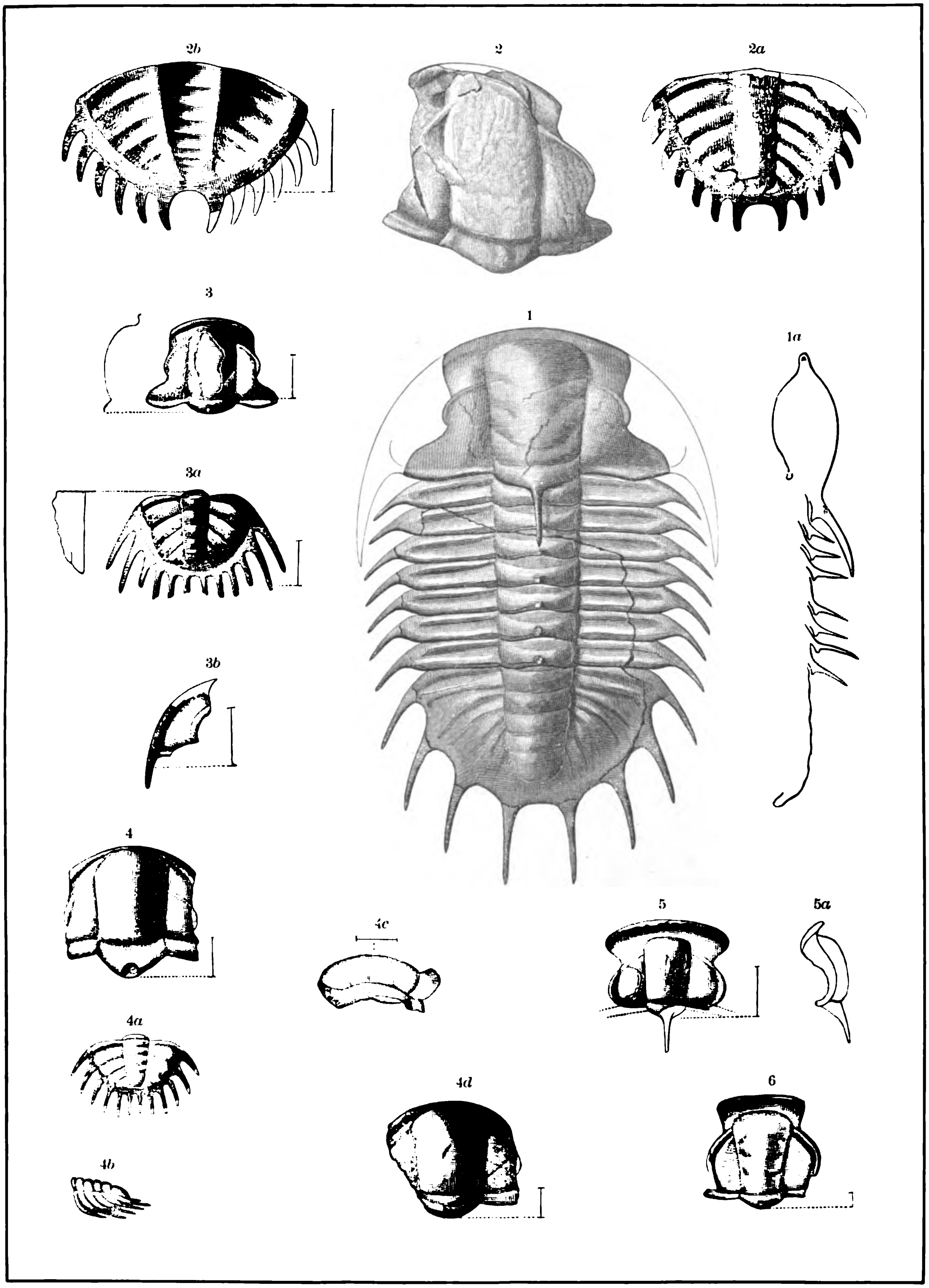
Zacanthoides levis 646

Fig. 5. View of the type specimen. Collection U.S. National Museum.

5*a*. Side view of 5.

Zacanthoides eatoni 646

Fig. 6. View of the type specimen, from Washington County, N.Y. Collection U.S. National Museum.



TRILOBITA.

PLATE XCV.

Plate XCV.

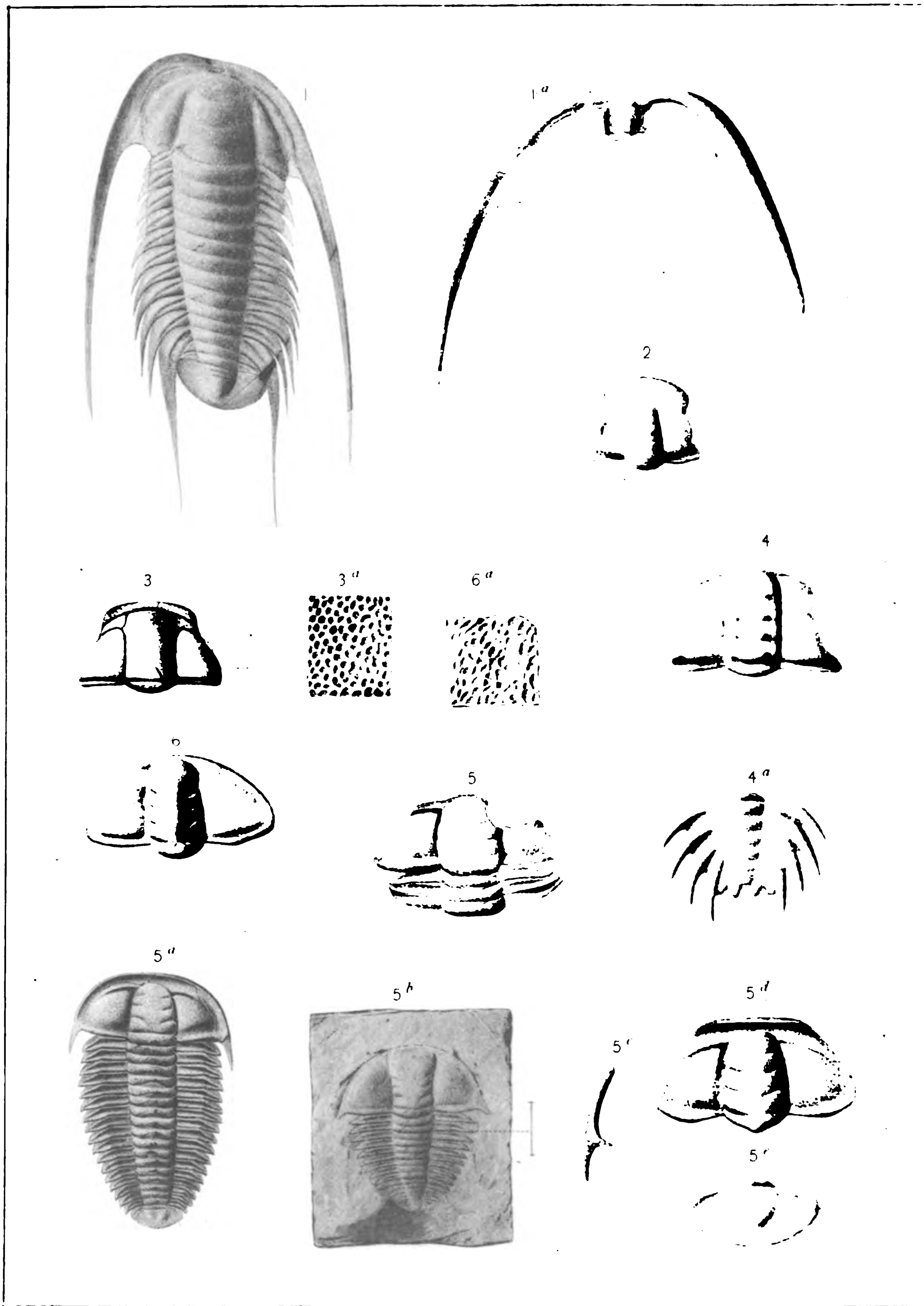


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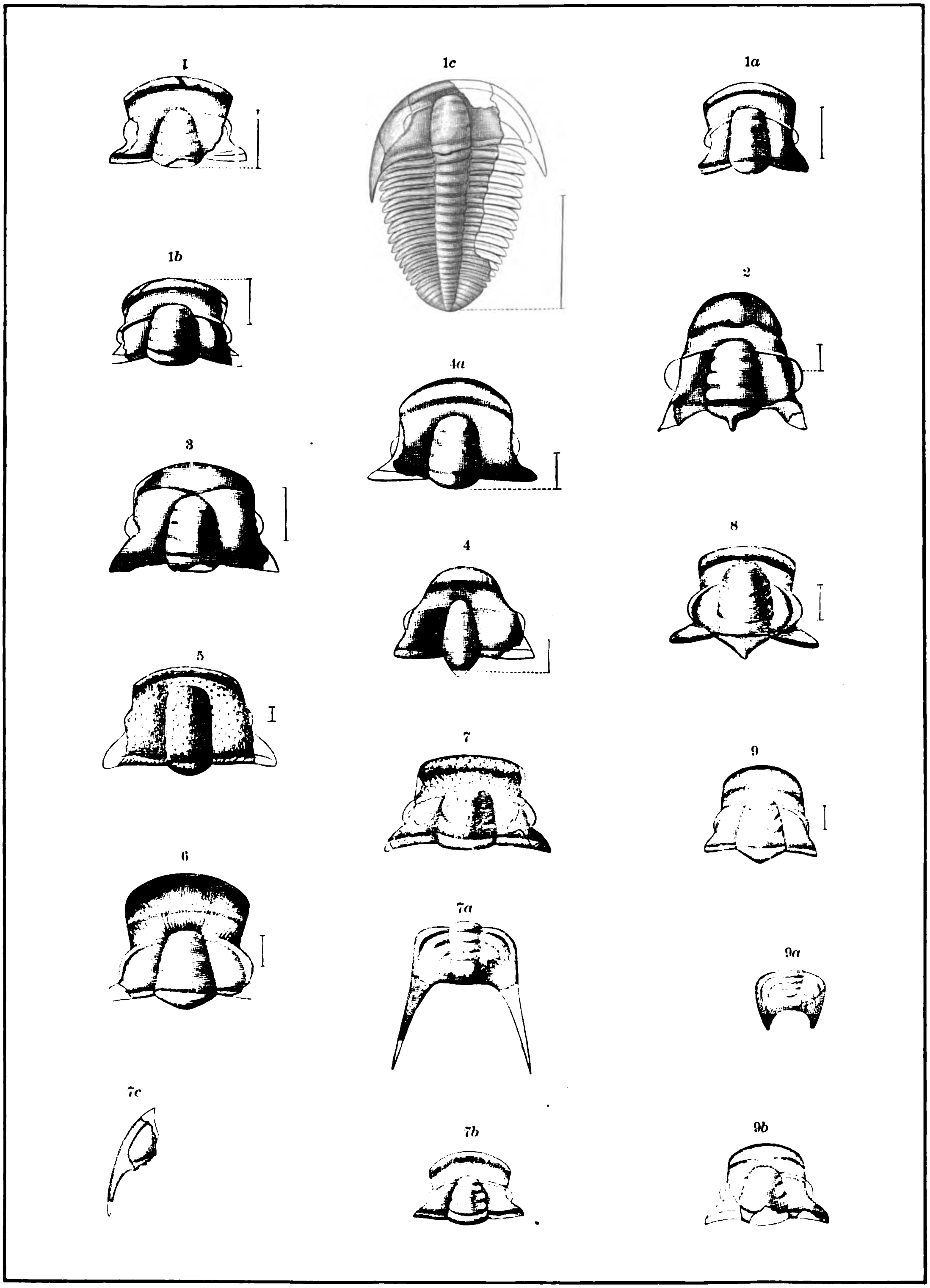
PLATE XCVI.

Plate XCVI.



TRILOBITA.

PLATE XCVII.

Plate XCVII.

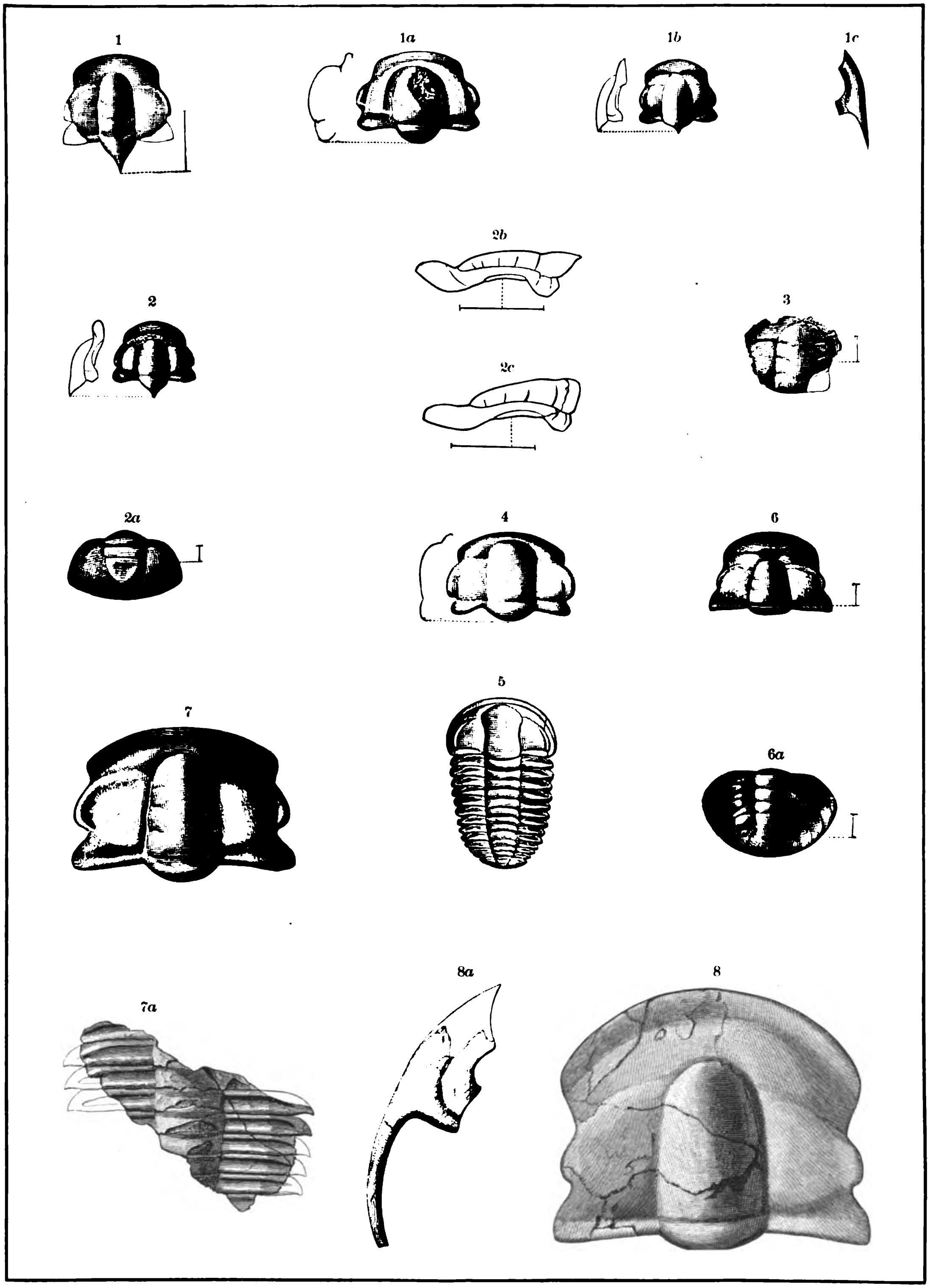


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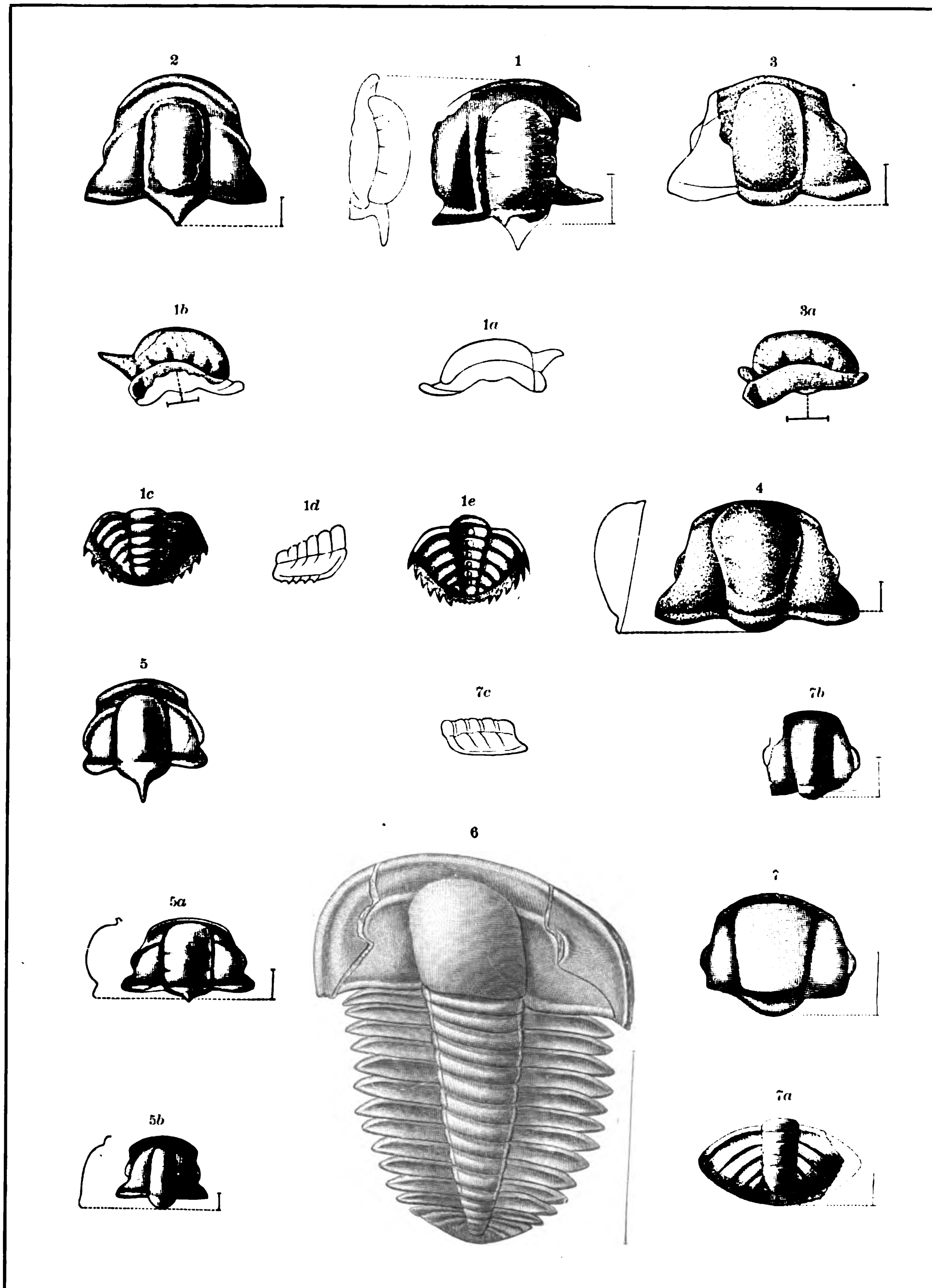
PLATE XCVIII.

Plate XCVIII.



TRILOBITA.

ERRATA.

Page 196, in tabular statement at foot of page, for Monograph II read Monograph XII.
Page 520, line 14 from top, for 1862 read 1861.
Page 525, lines 4 and 5 of title to Fig. 44, for Ordovician read Silurian.
Page 526, line 9 from top, and in table, for Ordovician read Silurian.
Page 547, line 4, for p. 566 read p. 564.
Page 552, line 4 from bottom, for upper portion read lower portion.
Page 552, line 2 from bottom, for 700 feet read 50 feet. (Discoveries made in August, 1890.)
Page 557, line 19, for section B read section 2.
Page 557, line 21, for section H read section 9.
Page 557, line 14 from bottom, for p. 552 read p. 550.
Page 557, line 12 from bottom, for p. 551 read p. 549.
Page 557, line 10 from bottom, for p. 552 read p. 550.
Page 557, line 4 from bottom, for p. 553 read p. 551.
Page 557, bottom line, for p. 554 read p. 552.
Page 558, line 2, for p. 561 read p. 559.
Page 558, line 7, for p. 561 read p. 559.
Page 558, line 20, for p. 555 read p. 553.
Page 558, line 20 from bottom, for p. 556 read p. 554.
Page 558, line 6 from bottom, for p. 551, p. 552, p. 552 read p. 549, p. 550, and p. 550, respectively.
Page 558, line 4 from bottom, for p. 553, p. 554 read p. 551 and p. 552, respectively.
Page 558, bottom line, for 556 read 554.
Page 559, line 6 of text, for Pls. XLV and XLVI read Pls. XLV and XLVII
Page 561, line 13 from bottom, for p. 552 read p. 550.
Page 564, line 8, for p. 549 read p. 547.
Page 564, line 3 from bottom, for (Mesonacis) read (Holmia).
Page 565, top line, for (M.) read (H.).
Page 565, line 6, for p. 556 read p. 554.
Page 565, line 19, for (Mesonacis) read (Holmia).
Page 567, line 16, for p. 546 read p. 544.
Page 568, line 5 from bottom, for (M.) read (H.).
Page 571, line 6, for p. 551 and p. 552 read p. 549 and p. 550, respectively.
Page 571, line 4 from bottom, for p. 552 read p. 550.
Page 575, line 10 of table, for Olenellus (Mesonacis) bröggeri read Olenellus (Holmia) bröggeri.
Page 576, line 6 from bottom, for Obutus pulchea read Obolus pulcher.

The name Silurian is now used to include both the Lower Silurian (Ordovician) and the Upper Silurian on the maps of the Geological Survey. Except that it is too late to make the changes in the text on pages 546, 547, 549, 552, 553, 563, and 568, this nomenclature would have been adopted in this paper. (C. D. W.). In the table, p. 547, the name Hudson is to be substituted for Lorraine.